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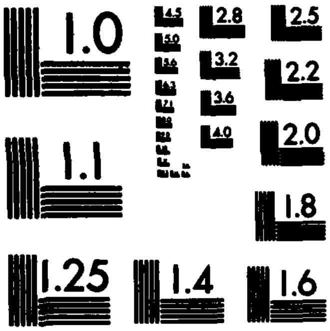

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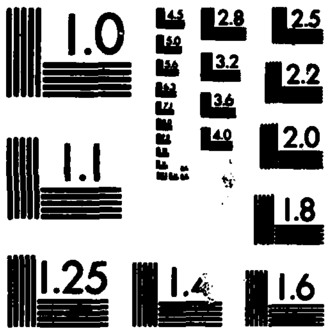

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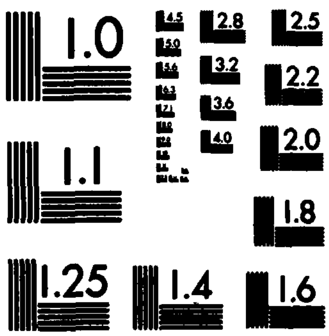

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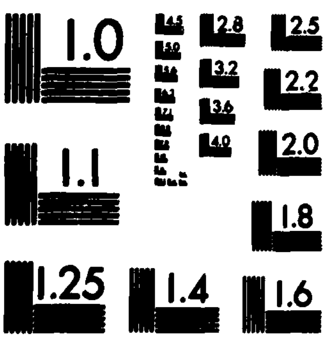

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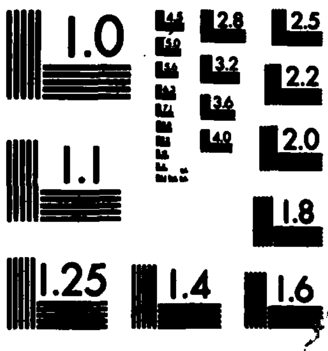

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MIDWEST RESEARCH INSTITUTE

REPORT

NATURAL RESOURCES STUDY TO DETERMINE CAUSES AND ALTERNATIVE SOLUTIONS TO THE SILTATION AND POLLUTION PROBLEMS OF BIG STONE LAKE

TASK I REPORT

DRAFT

MRI Project No. 3934-B

Contract No. DACW37-74-C-0107

For

U.S. Army Corps of Engineers
St. Paul District
1210 U.S. Post Office and Customs House
St. Paul, Minnesota 55101

MIDWEST RESEARCH INSTITUTE 425 VOLKER BOULEVARD, KANSAS CITY, MISSOURI 64110 • 816 561-0202

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The study describes the biological communities and aquatic ecosystems of the Big Stone Lake Watershed, estimated the amount of nutrient runoff, and considers alternative water quality improvement measures. This Phase 1 Study is to provide information on which to base a future project and does not authorize any project work. The Big Stone Lake Watershed borders Minnesota and South Dakota and is at the head of the Minnesota River. Poor water quality and sedimentation has reduced the lake's recreational value. Increases in ammonia nitrogen, nitrate nitrogen, and phosphorous characterize the nutrient changes in water quality.

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PREFACE

This preliminary draft includes the environmental inventory and detectable changes in water quality for the Big Stone Lake Watershed and is not the completed draft.

The study is under the direction of Dr. Alvin R. Hylton, Head, Ecological Assessments Section. Mr. Reid Flippin is Project Leader.

Contributions to this inventory were made by:

Ms. Carol Beardmore	Ornithology
Mr. Reid Flippin	Water Quality
Dr. Alvin R. Hylton	Historical and Archeological
Mr. William Knauer II	Terrestrial Animals
Mr. Bruce Krigel	Contemporary
Mr. Jerry Rasmussen	Aquatic Life
Ms. Karen Theisen	Geology and Hydrology
Ms. Margaret Thomas	Land Management
Mr. Bob Ward	Geology and Hydrology
Mr. Ralph Warner	Botanical

Approved for:

MIDWEST RESEARCH INSTITUTE

WB House/cc

W. B. House, Director
Biological Sciences Division

8 August 1974

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I. INTRODUCTION

A. Historical/Background

Big Stone Lake (Figure 1) lies in the valley of a former glacial river which drained Lake Agassiz, a large glacial lake covering most of North Dakota, northwestern Minnesota, and a small part of northeastern South Dakota during the ice age that ended about 8,000 years ago. The present Little Minnesota River flows through the glacial river valley in a southeasterly direction. Over geological time, a delta formed a natural dam near the present site of Big Stone City, South Dakota and Ortonville, Minnesota.[1/]

Big Stone Lake has a surface area of about 12,360 acres. Its length is about 24.6 miles and varies in width from 1/2 to 1-1/2 miles. The drainage area supplying surface water to Big Stone Lake is approximately 1,130 sq miles.[1/] The lake has been a summer resort area for more than 80 years, although the economy of the drainage area is predominantly agricultural.

Tributaries to Big Stone Lake include the Little Minnesota and Jorgenson Rivers, North Fork and South Fork of the Whetstone which form the Whetstone River, and various small streams in South Dakota; and Fish Creek and various small creeks and drainages in Minnesota.

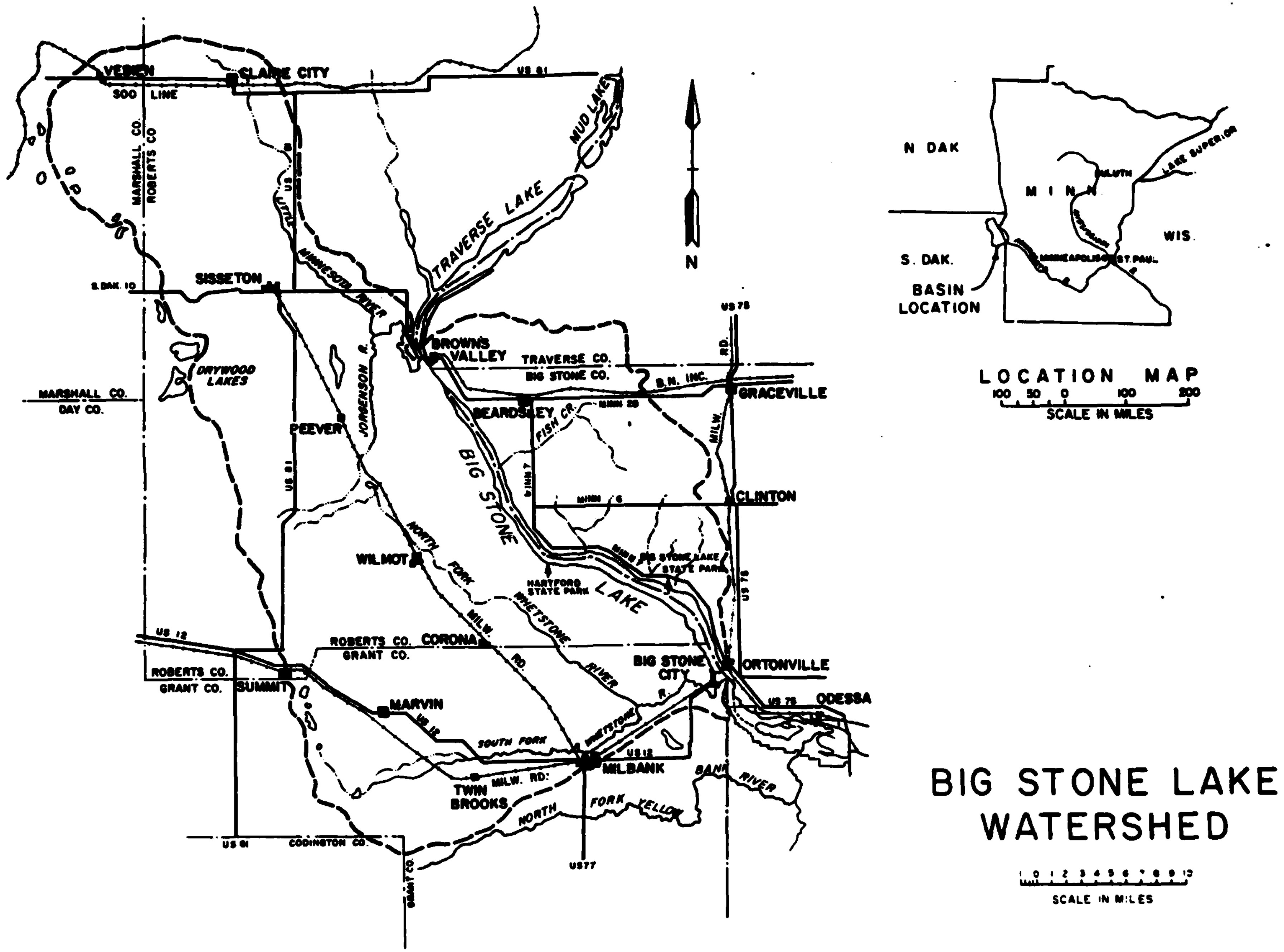
As a result of man's activities in the watershed area (agricultural, animal husbandry, industrial, domestic, etc.), excessive nutrient concentrations, primarily nitrogen and phosphorus, have produced nuisance growths of aquatic plants, including algal blooms, which affect water quality of that body of water. In addition to a degradation in the aesthetic value of Big Stone Lake, excessive dissolved solids and silts degrade surface waters and produce a detrimental effect on aquatic life.[2/]

B. Purpose of Study

The purpose of this study is to provide from existing data:

1. A general description of the major biological communities in the Big Stone Lake Watershed,

2. A general description of the existing aquatic ecosystems of the Big Stone Lake and the lower Whetstone and Little Minnesota Rivers,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ROBERTS CO
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LITTLE MINNESOTA RIVER
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DRYWOOD LAKES
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DAY CO.
BROWNS VALLEY
TRAVERSE CO.
BIG STONE CO.
B.N. INC.
GRACEVILLE
US 75
RD.
BEARDSLEY
FISH CR.
MINN 28
MILW.
PEEVER
JORGENSON R.
BIG STONE LAKE
MINN 7
MINN 6
CLINTON
BIG STONE LAKE STATE PARK
HARTFORD STATE PARK
WILMOT
NORTH FORK
WHETSTONE RIVER
MILW. RD.
US 12
ROBERTS CO.
GRANT CO.
CORONA
SUMMIT
BIG STONE CITY
ORTONVILLE
ODESSA
MARVIN
SOUTH FORK
WHETSTONE
MILBANK
TWIN BROOKS
NORTH FORK YELLOW BANK RIVER
US 81
CODINGTON CO.
GRANT CO.
US 77

Figure 1

3. An estimate of the nutrient runoff as pounds of nitrogen and phosphorus (acre/year) in the study area,

4. An estimate of the percentage by which nutrient runoff could be reduced with implementation of the best practicable land use measures based on existing technology,

5. The best possible description of any detectable changes in water quality or the aquatic ecosystem of the lake that can be determined, and

6. An analysis of alternative water quality improvement measures including estimates of costs and benefits.

C. Project Description

No project work is authorized for improvement of the nutrient problem in the Big Stone Lake. However, various studies have been made to provide information for use in delineating the contributing factors associated with water quality, and several alternatives which may be feasible for a recommended project plan. It is the purpose of this Phase I study to provide information on which a meaningful work project, if required, can be planned.

II. ENVIRONMENTAL INVENTORY

A. Biological Elements

1. Botanical: The post-pleistocene vegetation of the Big Stone Lake Watershed, before modification by man, was predominately tall grass prairie.[3,4] Other native plant communities of this area include the tree communities which are limited to the more moist sites within the watershed. Around potholes and lakes, semi-aquatic communities typified by rushes and sedges are present.

The plant communities found in this area result from low precipitation--20-24 in. annually--and a potential evapo-transpiration rate which equals or exceeds the precipitation.[4] Moisture during the spring and early summer months is adequate to support extensive grass communities and other plants which mature early in the growing season and become dormant during the periods of higher water stress.[5]

The tall grass prairie of this area is composed of such dominant species as quack grass, blue grama, side-oats grama, Junegrass, prairie grass, etc., along with over 100 species of forbs.[6] Presently, only remnants of the original vegetation is present. Over-utilization by livestock, conversion of prairie land to agricultural crops, and introduction of non-native plants has substantially altered the original prairie floral composition.

The marsh communities often remain essentially unaltered where they are still present. However, many of the marsh areas have been drained and converted to agricultural production. Still, many marshes, potholes, and lakes are present,[7] particularly along the western portion of the watershed, west of the Sisseton Hills moraine in South Dakota. The predominant taxa of these communities are the sedges, rushes, horsetail, cattail, etc.

Trees are a minor part of the overall plant community. A list of the trees which occur in this geographical area may be found in Appendix A. Bur oak, American elm, green ash, basswood, cottonwood, and willow are the predominant trees of the watershed area.[8]

2. Zoological

a. Terrestrial animals

(1) Arthropod fauna: The arthropod fauna of the Big Stone Lake Watershed area are typical of those species found in western Minnesota and eastern South Dakota, and are of no major significance with

respect to impacts from the water resources operations of the Corps of Engineers. The arthropods of greatest importance in the watershed are the medically and economically important insects.

(a) Medically important species: Although only limited field studies have been conducted in the watershed area, many species of mosquitoes, ticks, flies, midges, etc. have been identified in or around the area.[9-11] Most of these insects are merely nuisance pests which irritate rather than actually transmit a disease. While there may be no significant foci of insect-borne diseases in the region,[10] the primary vector of both western and St. Louis encephalitis, Culex tarsalis, has been reported in the area.[11] This mosquite vector has also been incriminated in the transmission of Venezualean equine encephalitis and Turlock and Cache Valley viruses in eastern South Dakota.[11] Price[10] believes that both western equine encephalitis and California encephalitis may occur in the watershed area. It appears, then, that at least two or three of the encephalitides occur in the area, and that the chief vector is Culex tarsalis (see Table 1).

At least nine other mosquito species have been collected in and around the watershed area. Eight of these were species of the genus Aedes and one was Culiseta inornata, a known carrier of both California encephalitis and western equine encephalitis[9] (see Table 1). Seven of the eight Aedes species are aggressive biters of man and animals. Their fierce biting habits make them important nuisance pests, seriously restricting man's recreational activities. These mosquitoes breed in temporary collections of water in drainage ditches, depressions, the marshy edges of lakes, potholes, etc. They also adversely affect horses and livestock because of biting activities (see Table 1).

In addition to the mosquitoes, a number of species of ticks, tabanids, blackflies, and biting midges occur in and around the watershed. Some of these arthropods are severe biting pests of man and animals, and some transmit diseases (see Table 1).

The extensive sources of the arthropods (especially mosquitoes) discussed above indicate that little or no consideration has been given to their control by ecological or environmental management of water. For example, ponding of water due to lack of drainage facilities and the use of roadside borrow ditches as drainage outlets for agricultural and other lands, constitutes a major source of mosquito breed sites. Prolific production of mosquitoes is probably widespread in highway cloverleafs and borrow areas so constructed as to result in extensive ponding of surface runoff. Man-made marshes created by flood control dikes and other water control dike structures are usually important localized sources of mosquitoes. The extensive production of mosquitoes

TABLE 1

INSECT PESTS OF MAN AND ANIMALS IN AND AROUND BIG STONE LAKE WATERSHED

Species	Importance
Mosquitoes	
Aedes dorsalis	Biting pest; may transmit California and western equine encephalitis
Aedes campestris	Biting pest
Aedes fitchii	Biting pest
Aedes flavescens	Biting pest
Aedes intrudens	Biting pest
Aedes riparius	Biting pest
Aedes sticticus	Biting pest
Aedes stimulans	Biting pest
Culiseta inornata	Vector of California and western equine encephalitis
Culex tarsalis	Vector of St. Louis and western equine encephalitis
Ticks	
Dermacentor variabilis	Vector of tularemia and Rocky Mountain Spotted Fever
Ixodes spp.	Vector of Powassan encephalitis
Horseflies and Deerflies	
Tabanidae	Biting pests and transmit disease to man and livestock (tularemia, anaplasmosis, leucocytozoons)
Blackflies	
Simulium spp.	Biting pests and transmit disease to wild and domestic birds.
Midges	
Culicoides spp.	Biting pests and transmit disease to livestock (blue tongue, onchocerca, horse sickness)

Source: References 9-11.

found in association with wildlife refuges demonstrates the need for soil and water management practices that would be of mutual benefit to mosquito control and wildlife conservation. Improper water and soil management procedures for pasture lands result in heavy mosquito production and illustrate the need for improved environmental measures that would be beneficial to both agriculture and vector control.

In contrast to these habitats that are highly productive of arthropod vectors, certain other habitats create no mosquito or other vector problems. The absence of species production in aquatic habitats demonstrates that ecological or environmental management of water and related land resources can be carried out in a manner that is mutually beneficial to agriculture, outdoor recreation, wildlife conservation, and public health.

(b) Economic (crop) pests: The principal crops in and around the Big Stone Lake Watershed are soybeans, cereal grains, and corn. While there are several insect pests which attack these crops, and at times cause very significant losses, the degree of impact varies from year to year depending on weather conditions (the microclimate) and flooding. In fact, high water is a greater problem than the insects themselves.[12/] The principal crop pests in the area are shown in Table 2.

(2) Terrestrial wildlife: The Big Stone Lake Watershed lies within the area of the tall-grass prairie biome.[13/] The habitat in the area is primarily of two types, croplands and prairie-pothole areas, but stands of trees exist in low areas and along streams.

Although the habitat is conducive to large numbers of herpetological species, the more northerly latitude tends to limit the actual resident species. The watershed is within the geographic range of two species of salamanders, five species of frogs and toads, three species of turtles, and nine species of snakes and lizards.

The turtles, salamanders, and amphibians in the watershed will be found predominantly along the streams, lakes, potholes, and marshes in the area. Most of the snakes in the area are species commonly found in grassland in prairie habitats.

Appendix B lists the species whose geographical range includes the Big Stone Lake Watershed. Also shown are the habitat preferences and restrictions of each species and the estimated population levels.

There are no known reptiles or amphibians which are considered nationally rare or endangered.[15/] Minnesota and South Dakota do not have state rare or endangered lists.

TABLE 2

PRINCIPAL CROP INSECTS IN THE BIG STONE LAKE WATERSHED AREA

Species	Crop Damaged
Pyrausta nubilalis (European corn borer)	Corn
Diabrotica spp. (Corn rootworm)	Corn
Plathypena scabra (Green cloverworm)	Soybean
Cutworms	Cereal grains, soybeans, corn
Flea Beetles	Cereal grains, soybeans, corn
Cirphis unipuncta Armyworm	Cereal grains and corn

Source: Reference 12

There are 55 species of mammals which possibly occur in the Big Stone Lake Watershed. Of these, 14 are normally considered furbearers and six are classified as game animals. The furbearers include the raccoon, short-tailed weasel, least weasel, long-tailed weasel, mink, badger, spotted skunk, striped skunk, coyote, red and gray fox, bobcat, beaver, and muskrat. The game animals are gray and fox squirrel, cottontail, snowshoe hare, mule and whitetail deer. Deer and cottontail populations in the past have been regarded as high in the area[18] with other populations about average for the type of habitat. The mixture of marsh, prairie, potholes, cropland, and wooded stream bottoms provides an excellent variety of food, cover, and edge for the various mammalian species. At one time prior to pressure from the white man, this area also played host to the lynx, moose, elk, bison, cougar, and wolf.[19] Presently, whitetails are found throughout the basin and mule deer are seen and harvested occasionally. Cottontails are also found over the entire basin with the occurrence of a snowshoe hare being unusual. The squirrels, as would be expected, are confined to the areas of woody vegetation. The coyote, fox, and bobcat would also be found over most of the basin. Appendix C lists the mammals possibly cccurring in the Big Stone Lake Watershed and also shows estimated population levels, and habitat preferences.

Recent studies[20] indicate that hunting resources in this area will be adequate to meet the hunter demand at least through the year 2020. There are no known nationally or regionally endangered mammals in the Big Stone Lake Watershed,[15] and Minnesota and South Dakota do not, as yet, have state rare or endangered lists.

b. Ornithological: The Big Stone Lake Watershed has 270 bird species[24] which have ranges that overlap or border the watershed (Appendix D). Of these 270 species, 97 birds have been identified in breeding bird counts[29,30] or Christmas bird counts.[26-28] Thirty-four birds are classified as permanent residents, 125 as summer residents, 26 as winter residents, and 84 which are transient or migrate through the area.[24] The habitat for the avifauna in the watershed is described as approximately 64% cropland, 30% grassland (for pasture and hay) and woodlands, and 6% municipal (which includes roads and urban waters).[31] This habitat area favors the 87 bird species that are prairie and cropland dwelling species.

As human population increases in the area, and along with it commercial and residential development, available habitat for certain species decreases. This results in the reduction of the species native to that habitat. Only Minnesota retains a sizable block of what was once the extensive prairie breeding range for waterfowl in the Mississippi Flyway. However, that which remains is decreasing through drainage and poor land management practices. The effect is felt mainly by waterfowl and to some

extent upland game. Because of human activities and lack of suitable nesting cover there is very little waterfowl production on Big Stone Lake itself. However, it does provide a resting site for large flights of migrating waterfowl. Ducks and geese coming from summer breeding grounds in Canada and North Dakota stop at the Big Stone Lake area on their way to wintering grounds. This migration corridor is used by up to 600,000 diving and dabbling ducks and up to 150,000 Canadian geese (blue and snow geese density was described as "heavy").[32] The pothole prairie surrounding the lake does provide breeding habitat for ducks at the rate of 6-15 breeding ducks per square mile.[33] The federal and state governments own 8,121 acres of land managed as refuges, waterfowl production areas, and wildlife management areas in the watershed. This land provides a protected breeding habitat for many birds and wildlife as well as waterfowl. Waubay National Wildlife Refuge, 13 miles to the west of the Big Stone Lake Watershed, is considered a link in the Central Flyway chain of refuges.[36] Although Hawkins[33] would probably place it in the Mississippi Flyway. This discrepancy illustrates that the watershed area is on the periphery of both the Central and Mississippi Flyways.

Upland game species distribution and composition has been substantially altered with urban development and land use practices. Ranges of the greater prairie chicken, the ruffed grouse and sharp-tailed grouse have decreased because of the prairie being plowed and the forest being cleared for agriculture. Prairie chickens were observed until about 1940 in eastern South Dakota. Some efforts to reintroduce them have not been successful.[35] One prairie chicken was sited in the 1971 Christmas bird count on the Tewaukon Refuge, North Dakota, 5 miles from the watershed.[26] Ruffed grouse were sited in 1971 and 1972 near Willmar, Minnesota, on the Christmas count.[26,27] Wild turkeys have never been native to South Dakota but have been successfully introduced to western Roberts County.[35] One turkey was sited in the 1971 Christmas bird count[26] and 18 were sited in 1973 (both sitings were near Willmar, Minnesota).[26] Pheasant, mourning dove, and gray partridge populations have benefited from man's agricultural practices. It is not known if there are any significant heronries or nesting raptors in the watershed.

Although the game hunting demand for the Souris-Red-Rainy and the remainder of the Upper Mississippi Watersheds will not be met in the future,[37] hunting demand in the Big Stone Lake Watershed has been projected as being satisfactory until the year 2020.[20] This is assuming that the habitat remains relatively stable. The 12% unsatisfied hunting need of the Upper Mississippi Watershed was not projected to be met in the next 50 years.[34] This might increase demand on the Big Stone Lake Watershed.

There are three threatened or endangered species whose ranges could include the Big Stone Lake Watershed. These are:

Southern Bald Eagle (possibly wandering northward)
Haliaeetus leucocephalus leucocephalus
Arctic Peregrin Falcon
Falco peregrinus tundrius
Northern Greater Prairie Chicken[23]
Tympanuchus cupido pinnatus

The American osprey (*Pandion haliaetus carolinesis*) and the Eastern pigeon hawk (*Falco columbarius columbarius*) are classified as status-undetermined. More information is needed to determine whether they are threatened with extinction.[23] The Audubon Society has compiled the Blue List which is a list of birds that have recently given indications of noncyclical population declines either locally or throughout their ranges. Twelve species whose ranges could include the watershed are on the Blue List.[25] These include the following:

Red-Throated Loon
Red-Necked Grebe
White Pelican
Double-Crested Cormorant
Cooper's Hawk
Osprey
Sparrow Hawk
Black-Crowned Night Heron
Franklin's Gull
Barn Owl
Bewick's Wren
Bell's Vireo

State rare or endangered species lists have not been compiled for either Minnesota or South Dakota.

c. Aquatic

(1) Habitats: The major lotic habitats of the Big Stone Lake area are provided by the Little Minnesota River, Fish Creek, Meadowbrook, and Whetstone Creek. Most of the other inlets are seasonal and run only a very short distance from the lake.[38] Thus, they provide very unstable conditions and contribute little to the overall fishery.

The Little Minnesota River bottom is composed mostly of sand while some muck can be found in the pool areas. Average width and depth are 130 ft and 2.5 ft, respectively.[38] The marshy area near

the lake provides excellent spawning habitat for northern pike and cattail (Typha sp.) and reed grass (Phragmites communis) provide cover near the shoreline.[38/] Every spring the river supports a large run of northern pike and rough fish, however, few walleye use this river for spawning.[38/]

Fish Creek also provides a good area for northern pike spawning.[38/] Average width and depth are 6 ft and 1.5 ft, respectively. The bottom is composed of sand and gravel with some rocks a short distance upstream from the lake.[38/] This sand and gravel substrate may be suitable for walleye spawning, however, it is apparently not used for such. Marshy areas, occupying a distance of 2-3 miles upstream, provide excellent pike spawning habitat and cover for newly hatched young. Fish Creek inlet is also used annually for spawning by a large number of rough fish.[38/] However, walleyes do not use this inlet for spawning even though a small area of suitable habitat is provided near the lake.[38/]

Meadowbrook is blocked by a beaver dam which effectively stops upstream fish migration 200 yd above the lake.[38/] The area below the dam provides marginal spawning habitat for northern pike because shoreline cover is limited to brush and trees.[38/] The Meadowbrook substrate is composed of sand and muck with a few boulders scattered throughout. Average width and depth are 15 ft and 0.5 ft, respectively, while average flow is 2.7 cfs.[38/] No large runs of spawning fish have been noted in this inlet.[38/]

Whetstone River experiences very large spring runoffs, but does not support large spawning runs. Flows ranged from 4.5 cfs to 1,990 cfs. Average width and depth is 50 ft and 1 ft, respectively.[38/] Little or no adequate spawning habitat is available for game fish below Big Stone City.[38/] Industrial and domestic pollution from sites in and around Big Stone City probably effect a barrier to upstream movement of spawning fishes.[38/] The stream bottom of Whetstone River is composed of sand with some intermittent areas of muck and silt in the lower reaches.[38/] Farther upstream, gravel, rubble, and sand predominate with algae coating the rocks in riffle areas. Some narrowleaf pondweed (Potamogeton strictifolius) can be found in the deeper pools.[39/] Resident stream fishes probably use this area for spawning, as walleye and other lake species probably would if their upstream migrations were not blocked by pollution.

The Minnesota River below Big Stone Lake averages 60 ft in width and 2 ft in depth. Flows range from 74.4-241.0 cfs.[38/] A dam located 0.25 miles below the lake forms a barrier to upstream migration.[38/] Thus, the importance of the lower Minnesota River to the Big Stone Lake study area is extremely limited with respect to fish migrations.

Lentic habitats of the Big Stone Lake region are not limited to Big Stone Lake itself. The numerous small lakes and marshes located on either side of the lake have not been thoroughly studied, but should provide a productive fish habitat. However, most of these bodies of water are primarily managed for waterfowl production, and the fish populations in most cases are probably limited to rough fish. The shallow depths associated with these lakes may also lead to chronic winter-kill problems, thus negating their usefulness.

Big Stone Lake is a shallow, narrow lake of glacial origin.[39] It is unique in that it lies on the continental divide separating the Arctic Ocean from the Gulf of Mexico.[40] Although it is just a few feet below the divide at Brown's Valley, fish dispersal between Big Stone Lake and Traverse Lake is effectively blocked even during spring flooding.[41]

The surface area of Big Stone Lake averages 12,610 acres. Twelve thousand acres or 95% of the total has been classified as littoral (i.e., that portion of the shoreward profile inhabited by macrophytes, algae, and autotrophic plants[42]) due to the overall shallow nature of the lake.[38] Maximum depth is 16 ft, length of shoreline is 61.85 miles and greatest length is 26.0 miles.[38] Water levels annually fluctuate from 3 ft above normal to 1 ft below normal. Long term fluctuations may be from +5 to -2 ft with ordinary spring runoff levels approximately 3 ft above normal. However, during the drought of the 1930's Big Stone Lake was 8-10 ft below normal levels.[38] During this period the size of the lake was greatly reduced.

The lake shorelines include domestic developments, mostly south of the Foster Lodge--Hartford Beach area, with scattered areas of development in the north end[38] and open farmland or mixed forest vegetation. Shorelines are flat to moderately sloped. The shoals consist of 20% boulders, 20% rubble, 10% gravel, 15% sand, 10% silt, and 25% muck.[38] Marshy areas are restricted to the extreme north end of the lake near Brown's Valley and a small area at the foot of the lake near Big Stone City. Emergent vegetation found in these areas include the following: river bulrush (*Scirpus fluviatilis*), common spikerush (*Eleocharis palustris*), reed grass, and northern arrowhead (*Sagittaria cuneata*).[43]

Submergent aquatic vegetation has been a problem in previous years.[66] However, during the 1971 survey it was not described as being a problem and was found only in a narrow band around most of the shoreline with increased concentrations in the north end in Peninsula Bay and between the islands and the South Dakota shoreline.[38] Species of plants include coontail (*Ceratophyllum demersum*), sago pondweed (*Potamogeton pectinatus*), and narrow leaf pondweed.[38] Under normal

conditions a shallow lake could be expected to support dense growths of submergent vegetation throughout its depths, provided that fertility was not a limiting factor and that the water was clear enough for sunlight to reach the bottom sediments. In the case of Big Stone Lake one factor which appears to limit rooted vegetative growth is turbidity which is caused by dense algal growth and colloidal silt. The depth of visibility has been recorded to range from 1.0-3.5 ft.[38/] Growth of rooted aquatic vegetation would be restricted below these depths.

High levels of sulfates limit the number of plant species in the Big Stone Lake region.[47/] Generally, only those species capable of tolerating average sulfate levels in excess of 250 ppm would be expected in the ponds, lakes, and streams of the area. A list of plant species known to occur in Minnesota waters and to be tolerant of high sulfate levels is included in Appendix E.

(2) Plankton: The rough fish population of Big Stone Lake is very large, as indicated by the commercial carp harvest (Table 3). Usually lakes with large rough fish populations experience algal blooms during the summer.[67/] This is partially caused by bottom feeding fish such as carp which continually stir the lake bottom and release nutrients from the mud, making them available to the algae.[67/]

TABLE 3

POUNDS OF FISH REMOVED COMMERCIALLY FROM BIG STONE LAKE SINCE 1960-61

Year	Carp	Buffalo	Sucker	Freshwater Drum	White Bass	Bullhead
1972-73	544,000	82,700	15,100	14,200	23,350	57,450
1971-72	210,744	14,850	38,055	141,900	51,980	26,241
1970-71	482,000	31,850	4,200	204,300	29,500	--
1969-70	79,245	41,585	25,585	49,795	66,130	--
1967-68	356,008	61,420	--	182,410	15,365	--
1965-66	177,165	83,430	--	189,545	56,115	--
1964-65	267,475	20,800	--	49,100	38,300	70,200
1963-64	354,495	36,090	27,740	387,965	56,735	--
1962-63	235,375	103,225	10,625	441,499	--	--
1961-62	105,950	7,320	10,045	355,640	--	--
1960-61	153,070	2,450	6,830	602,773	--	--

Source: Minnesota Department of Natural Resources.

Additional sources of nutrients are organic in the form of both aquatic plants and animals. All these forms of life contain nutrients and after their deaths, the nutrients are recycled through biological decomposition.

Algae benefit most directly from nutrient enrichment. There are three general types of algae common to Big Stone Lake.66/

1. Flamentous algae growing on rocks along the shore or attached to submerged plants
2. Free floating planktonic algae of the cold water periods (41-70°F)
3. Planktonic blue-green algae that are abundant in the summer

Anabaena, Aphanizomenon, and Microcystis, members of the third group, have been reported as being responsible for the objectionable algal blooms. Other species of algae such as Chroococcus, Melosira, Pinobryon, Cyclotella, Fragilaria, Cladophora, and Ankistrodesmus have also been identified from the lake waters.66,68/

(3) Shellfish: Little is known of the status of shellfish populations in the Big Stone Lake region and none are known to be harvested commercially. Reference lists of Unionid mussels and aquatic snails whose geographic ranges include the Big Stone Lake region are included in Tables 4 and 5. The preferred habitat of each species is listed in the tables. Most of the species of mussels listed which inhabit streams are intolerant of substrates composed of shifting sand and this limits their distribution.65/

Generally, mollusks require an environment which can provide food, oxygen, and calcium for the shell. Mussels live best where a current of water brings suspended food material, oxygen, and some form of calcium within reach of the cilia lining their mantle cavity. For these reasons, more species of mussels are found in rivers than in lakes.75/ Snails being smaller, lighter, and more mobile are able to live almost anywhere there is water and vegetation and, therefore, are the principle mollusks in lakes and ponds.75/

(4) Benthic macroinvertebrates: Populations of benthic macroinvertebrates in Big Stone Lake have not been extensively studied. However, data is available for the period August 24-26, 1959, for the outlet of Big Stone Lake and the Minnesota River for a distance of 14.5 miles downstream (Table 6).

During this period the Minnesota and Whetstone Rivers were at extreme low flows. The diversion channel of the Whetstone River above the dam was dry except for a trickle of about 2 gpm (gallons per

TABLE 4

UNIONID MUSSELS POSSIBLY OCCURRING IN THE BIG STONE LAKE WATERSHED

Common Name	Habitat[a]	Scientific Name
Pig-Toed Mussel	LR, RL	Fusconaia undata[b]
Blue-Point Mussel	SS, SR, MR, LR	Crenodonta peruviana peruviana
Three-Ridged Mussel	SS	C. peruviana costata
Unknown	MR, RL	Amblema rariplicata[b]
Maple-Leaf Mussel	LR, RL	Quadrula quadrula
Pimple-Backed Mussel	MR, LR, RL	Q. pustulosa[a]
Buckhorn Mussel	LR	Tritgonia verrucosa
Bullhead Mussel	LR	Plethobasus cyphyus[b]
Lady-Finger Mussel	MR, LR	Elliptio dilatatus
White Heel-Splitter Mussel	SR, MR, LR, RL	Lasmigona complanata[b]
Floater Mussel	All	Anodonta grandis
Unknown	SS, SR, MHWL	Anodontoides ferussacianus[b]
Squaw-Foot Mussel	SR, MR, LR, RL	Strophitus rugosus
Mucket Mussel	MR, LR, RL	Actinonaias carinata[b]
Deer Toe Mussel	LR	Truncilla truncata[b]
Fragile-Paper Mussel	LR, RL	Leptodea fragilis[b]
Pink Heel-Splitter Mussel	MR, LR, RL	Proptera alata
Lilliput Mussel	LR	Carunculina parva
Black Sand Mussel	SR, MR, LR, RL	Ligumia recta latissima[b]
Fat Mucket Mussel	SS, SR, MR, LR, RL, HWL	Lampsilis radiata siliquoidea
Plain Pocketbook Mussel	MR, LR, R.	L. ovata ventricosa[b]
Unknown	LR	L. higginsi[b]
Hickory Nut Mussel	SS, SR, MR, LR	Obovaria olivaria

a/ SS - Small streams
SR - Small Rivers
MR - Medium size rivers
LR - Large rivers
RL - River lakes
P - Ponds
SWL - Soft-Water lakes
MHWL - Medium hard-water lakes
HWL - Hard water prairie lakes
All - All habitat types

b/ Known to occur in the Minnesota River above New Ulm.[75]

Sources: Dawley, Charlotte, Distribution of Aquatic Mollusks in Minnesota, Amer. Midl. Nat., 38:671-697 (1947).
Murray, Harold D. and Leonard A. Byron, Handbook of Unionid Mussels in Kansas, Museum of Natural History, University of Kansas, Lawrence, Misc. Pub. No. 28, pp. 184, May 10, 1962.

TABLE 5

AQUATIC SNAILS POSSIBLY OCCURING IN THE BIG STONE LAKE WATERSHED AND KNOWN TO OCCUR IN THE MINNESOTA RIVER

Scientific Name	Habitat[a/]
Valvata tricarinata	All
Amnicola limosa	All
Somatogyrus subglobosus	MR, LR
Pleurocera acuta tracta	MR, LR, RL
Lymnaea stagnalis appressa	All
L. palustris	SS, P, RL, HWL
L. emarginata	RL, HWL
Helisoma antrosa	SR, MR, RL, SWL, MHWL, HWL
H. trivolvis	All
H. campanulata	SS, SWL, MHWL, HWL
Planorbula armigera	SS, P, SWL, MHWL
Menetus exacuous megas	P, SWL, MHWL
Physa gyrina	SR, MR, P, SWL, MHWL, HWL
P. integra	SR, MR, MHWL

Source: Dawley, Charlotte, Distribution of Aquatic Mollusks in Minnesota, Amer. Midl. Nat., 38:671-697 (1947).

a/ SS - Small streams
SR - Small rivers
MR - Medium size rivers
LR - Large rivers
RL - River lakes
P - Ponds
SWL - Soft-water lakes
MHWL - Medium hard-water lakes
HWL - Hard-water lakes
All - All habitat types

TABLE 6

BENTHIC MACROINVERTEBRATES COLLECTED FROM THE MOUTH OF BIG STONE LAKE, THE OUTLET TO BIG STONE LAKE, WHETSTONE DIVERSION, AND THE MINNESOTA RIVER BELOW BIG STONE LAKE, AUGUST 24-26, 1959
(Expressed as no./yd^3 of bottom area)

Taxa	Class a/	Station b/ BS-1	BS-2	D-2	D-2.2	D-1	M-0.3	M-3.5	M-7	M-14.5
Class - Insecta										
Order - Diptera										
Family - Tendipedidae										
Tanytarsus sp	F	1,800	16,200	1,980	5,184					
Tanypus sp	F				576			4,032		
Tendipes tentanus	F							11,520		
Tendipes sp	P		2,160							
Anatopynia sp	F	360	2,160	530						
Brillia sp	F			180						
Spaniotoma sp	F	360		720						
Pentaneura sp	F	360								
Family - Ceratopogonidae										
Bezzia sp	F				288					
Order - Trichoptera										
Family - Leptoceridae										
Leptocella sp	C			36						
Class - Crustacea										
Order - Amphipoda										
Family - Talitridae										
Hyalella sp	F	15,120								
Class - Oligochaeta										
Order - Plesiopora										
Family - Naididae										
Dero sp	P			180						
Paranais sp	F	6,300	9,720	11,340	6,336					8,640
Naidium sp	P	1,480	7,560	2,340	2,304					
Family - Aeolosomatidae										
Aeolosoma sp	P				288					
Totals		25,780	37,800	17,306	14,976			15,552		8,640

Source: Minnesota Department of Health, Division of Environmental Sanitation, Section of Water Pollution Control. Report on Investigation of the Minnesota and Whetstone Rivers near Ortonville, Big Stone, and Lac qui Parle Counties, August 24-26, 1959.

a/ P - organism typically found in polluted environments.
F - organism may be found in both polluted and unpolluted environments.
C - organism typically found only in unpolluted environments.

b/ BS-1 - Big Stone Lake 100 ft out from mouth and 200 ft from bridge on SAR 12.
BS-2 - At the mouth of Big Stone Lake and 100 ft from bridge on SAR 12.
D-2 - At bridge on SAR 12 outlet to Big Stone Lake.
D-2.2 - Outlet to Big Stone Lake 200 ft below bridge on SAR 12.
D-1 - Bridge on U.S. Hwys. 12 and 77 Whetstone diversion near South Dakota stateline.
M-0.3 - Minnesota River bridge on U.S. Hwys 12 and 77 below Ortonville dam.
M-3.5 - Minnesota River bridge on SAR 9, 3.5 miles below Ortonville.
M-7 - Minnesota River bridge on SAR 6 above Odessa.
M-14.5 - Minnesota River channel in Marsh Lake, bridge on SAR 10.

minute) flowing down the Whetstone River diversion channel and through the gate of the dam.[77] The level of the pool in the river above the dam was approximately 4 ft below the normal pool elevation.[77]

The lack of flow eliminated the dilution factor and caused the Minnesota River below the dam where the effluent from the Ortonville sewage treatment plant enters to become anerobic.[77] Gas bubbles and floating sludge were evident at Station M-0.3, and the river was found to be in an anerobic condition another 2.5 miles downstream.[77] Near Station M-7 the river was found to be dry in places.[77] The Whetstone River diversion channel at U.S. Highway 12 was also found to be anerobic.[77]

The organisms identified in Table 6 were collected with an Eckman dredge, and only those retained by a U.S. Standard No. 30 mesh screen were included in the samples.

Stations BS-1, BS-2, D-2, and D-2.2 comprise the Big Stone Lake portion of the study. Bottom sediments in this area are composed of silt deposited upon sand.[77] Samples collected at these stations revealed large numbers of Diptera larvae and Oligochaete worms (Table 6). These organisms are commonly found in habitats typified by decaying vegetation, mud bottom, and oxygen ranges from 10-60% of saturation.[77] The lack of species diversity and relative classification as pollutional organisms (Table 4) is indicative of present and past pollution.

Further study of bottom sediments in this area revealed the presence of large numbers of "clean water" Gastropoda (snail) shells in various stages of decay.[77] The complete absence of living members of this group is considered further indication of pollution.

The remainder of the stations shown in Table 6 represent the Minnesota River below Big Stone Lake with the exception of Station D-1, which was on the Whetstone River diversion channel.[77] The samples collected at stations D-1, M-0.3, and M-7 were completely devoid of macroinvertebrate organisms. Surface conditions at these stations were septic in nature. The samples from stations M-3.5 and M-14.5 contained fewer numbers and species of organisms than those collected at the lake outlet, but the organisms were of the same characteristic types.[77]

This study is somewhat biased since samples were only collected on one occasion and this was during a drought period. However, the lack of a well developed population of clean-water organisms and the paucity of species numbers at all stations are indicative of a polluted and deteriorating environment.

These data should not be interpreted to mean that all segments of the watershed are in a similar condition. Further study would be necessary to delineate the distribution of benthic macroinvertebrates over the entire watershed.

(5) Fish: The known fish fauna of the state of South Dakota consists of 93 species, none of which are restricted to the state.[39] Thirty-four species have been recorded in Big Stone Lake (Table 7) and 37 species have been recorded in the Whetstone River (Table 8). Collections have been rather extensive in the lake (Figure 2), so it is doubtful that additional studies would add any new species to the list. However, more careful study of the Whetstone River and the other larger tributaries may yield more species than are currently known.

A list of 38 species whose geographic range includes the general region of Big Stone Lake, but have not been collected in the project area, is included in Appendix F. However, it is doubtful that several of these species, including the rainbow trout and the smallmouth bass, could be located in the Big Stone Lake region due to their low tolerance of silt turbidity. According to Bailey and Allum, 10 species listed in Appendix F have either been reported from the watershed and their identifications have not been confirmed, or they are known to occur in the immediate vicinity of Big Stone Lake and should be looked for very carefully.[39]

Man's influence on the environment of the Big Stone Lake Watershed has probably been a factor in the disappearance of several of the species originally inhabiting the area. It is doubtful that the activities of the early Indian tribes were detrimental since they were nomadic, and their livelihood depended on the bison and other plains animals.[39] Fishes were utilized for food only as permitted by circumstances and chance. However, at the onset of homesteading by white settlers in 1863, the prairies were plowed and stream character changed rapidly with the increased silt load.[39]

Industrial and domestic pollution have also probably contributed to faunal changes in the Big Stone Lake Watershed, especially in recent years after the Whetstone River was diverted into the lake. These factors have been largely responsible for the continued enrichment and consequent eutrophic conditions currently being experienced in the lake. The effect of eutrophication on fish life is similar to that shown on all other forms of aquatic life (i.e., species composition is usually shifted from game fish to more abundant and less desirable rough fish[44]). In the case of Big Stone Lake, this phenomenon has been shown in decreasing numbers of northern pike and largemouth bass while numbers of carp and suckers have been ever increasing (see commercial fish harvest 1960-73, Table 3). Additionally, in order to maintain other game fish populations it has been necessary for fisheries managers to recommend periodic stocking of northern pike, walleye, bluegill, and crappie.[38]

TABLE 7

FISHES KNOWN TO OCCUR IN BIG STONE LAKE

Common Name*	Scientific Name*	Collection Dates 1947	1949-56	1971
Shortnose Gar	Lepisosteus platostomus			X
Northern Pike	Esox lucius	X	X	X
Stoneroller	Campostoma anomalum	X	X	X
Lake Chub	Couesius plumbeus			X
Carp	Cyprinus carpio		X	X
Brassy Minnow	Hybognathus hankinsoni	X	X	
Hornyhead Chub	Nocomis biguttatus		X	X
Emerald Shiner	Notropis atherinoides	X	X	X
Common Shiner	N. cornutus	X	X	X
Bigmouth Shiner	N. dorsalis	X	X	
Spottail Shiner	N. hudsonius	X	X	X
Sand Shiner	N. stramineus	X	X	
Bluntnose Minnow	Pimphales notatus	X	X	X
Fathead Minnow	P. promelas	X	X	X
Blacknose dace	Rhinichthys atratulus		X	
Creek Chub	Semotilus atromaculatus	X	X	
Quillback	Carpiodes cyprinus			X
White Sucker	Catostomus commersoni	X	X	X
Bigmouth Buffalo	Ictiobus cyprinellus			X
Black Bullhead	Ictalurus melas	X	X	X
Brown Bullhead	I. nebulosus	X		X
Yellow Bullhead	I. natalis			X
Brook Stickleback	Culaea iconstans		X	
White Bass	Morone chrysops	X	X	X
Rock Bass	Ambloplites rupestris			X
Pumpkinseed	Lepomis gibbosus		X	X
Orangespotted Sunfish	L. humilis			X
Bluegill	L. macrochirus	X	X	X
Largemouth Bass	Micropterus salmoides	X	X	X
White Crappie	Pomoxis annularis	X	X	X
Black Crappie	P. nigromaculatus	X	X	X
Iowa Darter	Etheostoma exile		X	X
Johnny Darter	E. nigrum	X	X	X
Yellow Perch	Perca flavescens	X	X	X
Walleye	Stizostedion vitreum	X		X
Freshwater Drum	Aplodinotus grunniens	X	X	X

Sources: Lake Survey Report - Big Stone Lake - Big Stone County, Minnesota Department of Natural Resources, June 21-24, 1947.
Also Reference Nos. 39, 50, and 78.

TABLE 8

FISHES KNOWN TO OCCUR IN WHETSTONE CREEK
(COLLECTION DATES: 1949-56)

Common Name*	Scientific Name*
Northern Pike	Exox lucius
Stoneroller	Campostoma anomalum
Carp	Cyprinus carpio
Brassy Minnow	Hybognathus hankinsoni
Hornyhead Chub	Nocomis biguttatus
Emerald Shiner	Notropis atherinoides
Common Shiner	N. cornutus
Bigmouth Shiner	N. dorsalis
Rosyface Shiner	N. rubellus
Sand Shiner	N. stramineus
Bluntnose Minnow	Pimephales notatus
Fathead Minnow	P. promelas
Blacknose Dace	Rhinichthys atratulus
Creek Chub	Semotilus atromaculatus
Quillback	Carpiodes cyprinus
White Sucker	Catostomus commersoni
Bigmouth Buffalo	Ictiobus cyprinellus
Golden Redhorse	Moxostoma erythrurum
Shorthead Redhorse	M. macrolepidotum
Black Bullhead	Ictalurus melas
Stonecat	Noturus flavus
Tadpole Madtom	N. gyrinus
Brook Stickleback	Culaea inconstans
White Bass	Morone chrysops
Rock Bass	Ambloplites rupestris
Pumpkinseed	Lepomis gibbosus
Bluegill	L. macrochirus
Largemouth Bass	Micropterus salmoides
White Crappie	Pomoxis annularis
Black Crappie	P. nigromaculatus
Iowa Darter	Etheostoma exile
Johnny Darter	E. nigrum
Yellow Perch	Perca flavescens
Blackside Darter	Percina maculata
Slenderhead Darter	P. Phoxocephala
Walleye	Stizostedion vitreum
Freshwater Drum	Aplodinotus grunniens

*Source: Bailey, R.M. and M.O. Allum, Fishes of South Dakota, Mus. Zool., Univ. Michigan, Misc. Publ. 119: 1-131, pl.1. June 5, 1962. Also Reference No. 78.

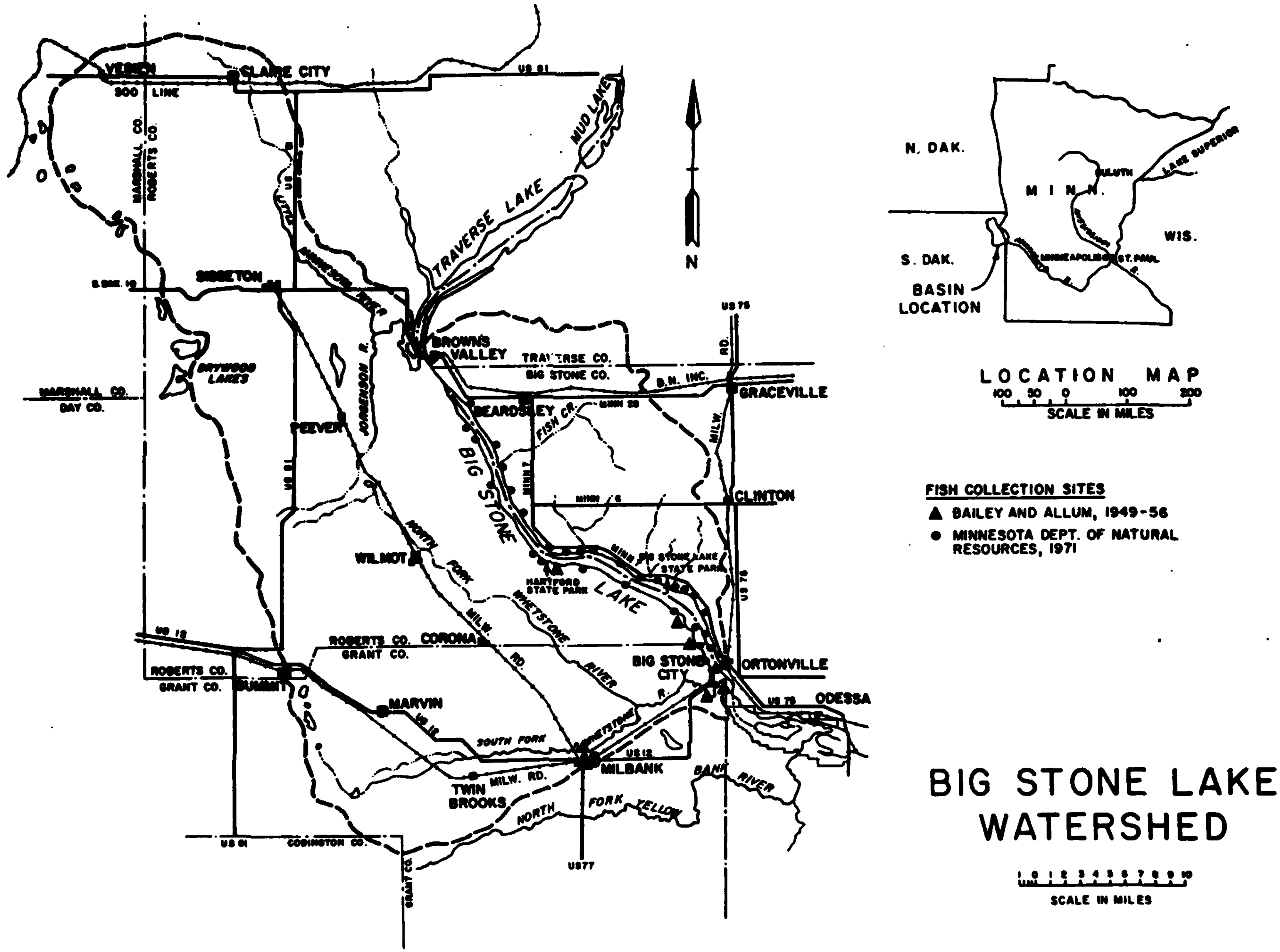

Figure 2 - Fish Collection Sites on the Whetstone River and Big Stone Lake, South Dakota, 1947-1971.

The introduction of the European carp into South Dakota waters in the late 1800's was also responsible for changes in the fish fauna of Big Stone Lake. Carp usually migrate into favorable waters as the opportunity exists and then gradually dominate the fish populations in polluted lakes or newly created habitats that are marginal or unsuitable for game fish. As carp populations increase in size their bottom feeding habits tend to roil the water, making it unfavorable for growth of rooted vegetation, fish, and fish food organisms.[45] They compete for bottom food,[46] interfere with spawning, and frequently crowd out other fishes.[45]

Nature has also played a role in changing the distribution of fishes in South Dakota, especially during the drought period of the late 1930's. During the worst of the dry years, only six lakes in South Dakota, including Big Stone, were known to have supported game fish.[39] During that time the water levels of Big Stone Lake were reported to be 8-10 ft below normal, so its overall surface area and volume were greatly reduced.[38] The results were increased salinity[42] and crowding of fish. The ecological effects would include increased predation on the smaller fishes[48] and possible extirpation of those species with low salt tolerance capabilities. Over a long period, through these mechanisms many species, especially the smaller, less tolerant ones, could have been eliminated from the watershed.

Currently nine species listed by South Dakota and Minnesota as threatened have been reported to occur in the Big Stone Lake Watershed (Table 9). All of these species are intolerant of large quantities of silt and any of them could easily be extirpated from the watershed with further increases in silt load. The black bullhead, more tolerant of silt than the yellow and brown bullheads,[49] is currently dominating the catch[38] and should not be confused with the other two species. The lake sturgeon has been reported from Big Stone Lake, but these reports have not been confirmed.[39] This species is also included on the U.S. list of threatened wildlife.[50] Pflieger suggests its decline in abundance to have resulted from a combination of increased siltation, overfishing, and dam construction which has blocked its movements and destroyed its habitat.[49] Threatened species will be discussed in greater detail later on in this report.

Fish hatchery facilities in the Big Stone Lake region include two ponds operated by the Minnesota Department of Natural Resources. Production records for the period 1961-1973 are included in Table 10. The largest of the two (21.1 acres) is located in section 14, R47W, T121N. It was originally constructed to supply walleye fingerlings for several west-central Minnesota county lakes and production is limited

TABLE 9

FISHES CONSIDERED THREATENED BY THE STATES OF MINNESOTA AND/OR SOUTH DAKOTA WHICH POSSIBLY OCCUR IN THE BIG STONE LAKE REGION

Common Name	Scientific Name	Status
Silver Lamprey	*Ichthyomyzon unicuspis*	endangered
Lake Sturgeon[a,b]	*Acipenser fulvescens*	endangered/rare[a]
Longnose Gar	*Lepisosteus osseus*	rare
American Eel	*Anguilla rostrata*	endangered
Mooneye	*Hiodon tergisus*	endangered
Central Mudminnow	*Umbra limi*	rare
Silver Chub	*Hybopsis storeriana*	rare
Hornyhead Chub[c]	*Nocomis biguttatus*	rare
River Shiner	*Notropis blennius*	rare
Blackchin Shiner	*N. heterodon*	endangered
Blacknose Shiner	*N. heterolepis*	endangered
Rosyface Shiner[c]	*N. rubellus*	rare
Northern Redbelly Dace	*Chrosomus eos*	rare
Blacknose Dace[c]	*Rhinichthys atratulus*	rare
Longnose Sucker	*Catostomus catostomus*	rare
Northern Hogsucker	*Hypentelium nigricans*	rare
Golden Redhorse[c]	*Moxostoma erythrurum*	rare
Yellow Bullhead[c]	*Ictalurus natalis*	rare
Brown Bullhead[c]	*I. nebulosus*	rare
Trout-Perch	*Percopsis omiscomaycus*	rare
Banded Killifish	*Fundulus diaphanus*	rare
Blackside Darter[c]	*Percina maculata*	rare
Slenderhead Darter[c]	*P. phoxocephala*	rare

a/ This species is considered rare in Minnesota and endangered in South Dakota, and is the only species listed by Minnesota which may occur in the Big Stone Lake region.

b/ Species included on the U.S. list of threatened wildlife.

c/ Species included in previous collections (see Tables 7 & 8).

rare: Not under immediate threat of extinction, but occuring in such small numbers and/or in such a restricted or specialized habitat that it could quickly disappear. Requires careful watching.

endangered: Actively threatened with extinction. Continued survival unlikely without the implementation of special protective measures.

See Refs. Nos. 15 and 62.

TABLE 10

BIG STONE LAKE FISH HATCHERY FACILITIES WITH POPULATION RECORDS FOR 1961 - 1973

A. 21.2-acre pond

Year	Species	Number Fingerlings Produced
1961	Walleye	No production
1962	Walleye	No production
1963	Walleye	21,405
1964	Walleye	13,240
1965	Walleye	552,580
1966	Walleye	171,705
1967	Walleye	362,765
1968	Walleye	No production
1969	Walleye	Pond not used
1970	Walleye	33,884
1971	Walleye	40,478
1972	Walleye	233,185
1973	Walleye	No production

B. 3-acre pond (Big Stone Park)

Year	Species	Number Fingerlings Produced
1971	Northern Pike	3,632
1972	Northern Pike	4,590
1973	Northern Pike	2,720

Source: Daly, Stanley A., Minn. Dept. Natural Resources, pers. communication (June 20, 1974).

to this species.[74] Since 1961 about 30% of the annual production of this drainable pond has been stocked in Big Stone Lake.[74]

The second pond, located in Big Stone Park, is smaller in size (3 acres) and is used to rear northern pike fingerlings.[74] This pond was first operated in 1971 and to date its entire production has been used in Big Stone Lake. No plans have been made to further expand hatchery facilities in the area. Instead, emphasis will be directed toward increasing production from present facilities.[74]

The South Dakota Department of Game, Fish, and Parks operates a fish hatchery consisting of three rearing ponds totaling 7 acres in size.[76] They are located in section 31, R46W, T122N, approximately 6 miles north of Big Stone City. Production in these ponds is limited to northern pike, walleye, and largemouth bass.[76] All fish raised in these ponds are not used in Big Stone Lake but total production records showing exact distribution are not available. Future plans for the ponds are uncertain, but they may be used to produce fingerlings for Big Stone and Traverse Lakes, operated in cooperation with a local sportsmen's group.[76]

Fisheries management in Big Stone Lake is a cooperative effort between the two states. Contract fishing, fish stocking, test netting, and regulations are reviewed annually and agreed upon by both states.[76] The current agreement calls for each state to stock 3 million walleye fry or equivalent on alternate years.[76] Complete stocking records for Big Stone Lake during the period 1966-1974 are included in Table 11.

The most recent fish population data available for Big Stone Lake was collected by the Minnesota Department of Natural Resources from June 17 to September 17, 1971. Summaries of the adult fish population structure are provided in Tables 12, 13, 14, and 15. Data presented in these tables were collected using three different methods to eliminate bias due to gear selectivity.

Gill net and trap net data (Tables 12 and 13) tend to indicate that the fish population of Big Stone Lake is dominated by yellow perch and black bullheads. Together they account for 57.09% of the trap net sample and 88.51% of the gill net sample. White bass rank as the third most abundant species, while numbers of carp and suckers are nearly insignificant.

Electroshocking data, on the other hand (Table 15), indicate that carp account for 16.59% of the sample and could thus be considered the second most abundant species in the lake.

TABLE 11

FISH STOCKING RECORDS FOR BIG STONE LAKE 1966-1974
(DATA INCLUDES STOCKING BY BOTH MINNESOTA AND SOUTH DAKOTA)

Year	Species and Size	Number Stocked
1966	Walleye Fry	3,000,000
	Walleye Fingerling	172,945
	Northern Pike Yearling	1,300
1967	Northern Pike Fingerling	1,998
	Northern Pike Yearling	12
1968	Walleye Fingerling	138
	Sunfish Fingerling	18,000
1969	Walleye Fingerling	160
	Northern Pike Yearling	60
	Northern Pike Adult	244
	Sunfish Fingerling	1,600
	Crappie Fingerling	6,240
	Bluegill Fingerling	21,600
	Largemouth Bass Yearling	80
1970	Walleye Fry	3,000,000
	Walleye Fingerling	128,178
	Northern Pike Fingerling	716
	Northern Pike Yearling	410
	Sunfish Yearling	1,332
	Bluegill Yearling	315
1971	Walleye Adult	4
	Northern Pike Fingerling	3,632
	Northern Pike Adult	21
1972	Walleye Fry	3,600,000
	Walleye Fingerling	425,935
	Northern Pike Fingerling	4,590
	Bluegill Fingerling	2,750
	Largemouth Bass Fingerling	2,400
1973	Northern Pike Fingerling	6,175
	Northern Pike Yearling	39
	Bluegill Fingerling	5,000
1974	Walleye Fry	3,000,000
	Walleye Fingerling	124,800

Definitions: Fry: Usually considered to be less than one inch in length and may still be obtaining nourishment from the yolk sac. Mortality extremely high.

Fingerling: Depending on species, may be one to six inches in length, and usually actively feeding. Survival much better than at fry stage.

Yearling: One year old, length will vary with species. Chances of survival are good.

Adult: Fully mature and capable of reproducing. Chances of survival are excellent.

Source: Daley, Stanley A., personal communication, Minnesota Department of Natural Resources, June 20, 1974.

TABLE 12

TRAP NET SURVEY BIG STONE LAKE, MINNESOTA, JUNE 17 - JULY 16 AND AUGUST 2-26, 1971[a/]

Species	Total Number	% of Sample	Number/Net This Study	Number/Net Statewide Median	Total Pounds	Pounds/Net This Study	Pounds/Net Statewide Median	Average Weight (lb) This Study	Average Weight (lb) Statewide Average
Bigmouth Buffalo (Ictiobus cyprinellus)	6	0.15	0.17	0.315	57.1	1.63	1.50	9.52	4.76
Quillback (Carpiodes cyprinus)	11	0.27	0.13	0.13	22.9	0.65	1.01	2.08	7.77
White Sucker (Catostomus commersoni)	28	0.69	0.80	0.625	105.0	3.28	2.12	3.75	3.39
Shorthead Redhorse (Moxostoma macrolepidotum)	99	2.44	2.82	0.33	260.5	7.45	0.91	2.63	2.76
Carp (Cyprinus carpio)	169	4.16	4.84	1.68	1175.3	33.36	4.515	6.94	2.69
Common Shiner (Notropis cornutus)	17	0.42	0.48	0.65	1.7	0.05	0.01	0.10	0.04
Hornyhead Chub (Nocomis bigguttatus	1	0.03	0.03	--	0.1	0.003	--	0.10	--
Black Bullhead (Ictalurus melas)	1,298	31.97	37.1	2.60	631.6	18.00	2.18	0.49	0.84
Brown Bullhead (I. nebulosus)	15	0.37	0.43	1.60	10.7	0.30	1.20	0.71	0.75
Yellow Bullhead(I. natalis)	224	5.52	6.70	2.63	219.4	6.25	1.88	0.98	0.71
Northern Pike (Esox lucius)	26	0.64	0.74	0.50	84.9	2.38	0.925	3.27	1.85
White Bass (Morone chrysops)	617	15.20	17.60	0.695	390.6	11.15	0.54	0.63	0.78
Yellow Perch (Perca flavescens)	1,020	25.12	29.10	1.50	178.5	5.11	0.26	0.18	0.17
Walleye (Stizostedion vitreum)	37	0.91	1.06	0.50	63.2	1.80	0.96	1.71	1.92
Largemouth Bass (Micropterus salmoides)	2	0.05	0.06	0.555	2.8	0.08	0.35	1.4	0.63
Orangespotted Sunfish (Lepomis humilis)	2	0.05	0.06	0.22	0.2	0.006	0.01	0.01	0.004
Pumpkinseed (L. gibbosus)	7	0.17	0.20	2.83	1.4	0.04	0.55	0.20	0.19
Bluegill (L. macrochirus)	165	4.06	4.72	11.67	62.5	1.78	2.48	0.38	0.21
Rock Bass (Ambloplites rupestris)	3	0.07	0.09	1.355	0.8	0.02	0.53	0.27	0.39
Black Crappie (Pomoxis nigromaculatus)	124	3.05	3.55	2.67	65.9	1.88	0.97	0.53	0.37
Freshwater Drum (Aplodinotus grunniens)	189	4.66	5.41	1.88	155.8	4.44	1.35	0.82	0.68

a/ Survey conducted by personnel of the Minnesota Department of Natural Resources using 35 trap nets.
Source: Minnesota Division of Game and Fish. Fisheries Lake Survey - Big Stone Lake, June 17-September 17, 1971.
Nomenclature in accordance with Bailey, R. M., et al., A List of Common and Scientific Names of Fishes from the United States and Canada. Third edition, Amer. Fish. Soc. Spec. Publ. No. 6, Washington, D. C. (1970).

TABLE 13

GILL NET SURVEY BIG STONE LAKE, MINNESOTA, JUNE 17-JULY 16 AND AUGUST 2-26, 1971[a/]

Species	Total No.	% of Sample	No/Net This Study	No/Net Statewide Median	Total pounds	Pounds/Net This Study	Pounds/Net Statewide Median	Average weight(lb) This Study	Average weight(lb) Statewide Average
Quillback (*Carpiodes cyprinus*)	1	0.02	0.04	0.29	1.5	0.07	0.35	1.5	1.21
White Sucker (*Catostomus cyprinus*)	54	1.17	2.35	1.90	123.9	5.37	2.53	2.29	1.33
Shorthead Redhorse (*Moxostoma macrolepidotum*)	22	0.48	0.96	0.34	42.8	1.86	0.70	1.95	2.06
Carp (*Cyprinus carpio*)	8	0.17	0.35	1.20	38.0	1.61	1.80	4.75	1.50
Black Bullhead (*Ictalurus melas*)	352	7.65	15.29	1.50	161.0	7.02	0.90	0.46	0.60
Brown Bullhead (*I. nebulosus*)	1	0.02	0.04	1.85	0.8	0.03	1.30	0.80	0.70
Yellow Bullhead (*I. natalis*)	12	0.26	0.52	1.19	13.4	0.58	0.70	1.12	0.66
Northern Pike (*Esox lucius*)	31	0.67	1.35	2.67	78.9	3.43	5.62	2.55	2.10
White Bass (*Morone chrysops*)	138	3.00	6.00	4.25	99.9	4.34	2.795	0.72	0.66
Yellow Perch (*Perca flavescens*)	3,722	80.86	161.5	8.00	1,187.6	51.60	1.51	0.32	0.19
Walleye (*Stizostedion vitreum*)	119	2.59	5.17	3.60	215.6	9.35	5.16	1.81	1.43
Pumpkinseed (*Lepomis gibbosus*)	4	0.09	0.17	1.17	1.0	0.04	0.20	0.25	0.17
Bluegill (*L. macrochirus*)	5	0.11	0.22	1.61	2.1	0.91	0.35	0.42	0.22
Black Crappie (*Pomoxis nigromaculatus*)	29	0.63	1.26	2.00	12.0	0.52	0.50	0.41	0.75
Freshwater Drum (*Aplodinotus grunniens*)	105	2.28	4.55	8.99	48.8	2.12	5.50	0.47	0.61

a/ Survey conducted by personnel of the Minnesota Department of Natural Resources using 23 experimental nets 250 ft in length.

Source: Minnesota Division of Game and Fish, Fisheries Lake Survey - Big Stone Lake, June 17-September 17, 1971.

Nomenclature in accordance with Bailey, R. M., et al., A List of Common and Scientific Names of Fishes from the United States and Canada, Third edition, Amer. Fish Soc. Spec. Publ. No. 6, Washington, D. C. (1970).

TABLE 14

LENGTH-FREQUENCY DISTRIBUTION OF FISHES COLLECTED FROM BIG STONE LAKE, MINNESOTA, JUNE 17-SEPTEMBER 17, 1971, USING GILL NETS AND TRAP NETS[a]

Total Length In Inches	Species and Numbers of Fish in Length Groups										
	Northern Pike	White Bass	Yellow Perch	Walleye	Large-mouth Bass	Orange-spotted Sunfish	Pumpkin-seed	Bluegill	Rock Bass	Black Crappie	Freshwater Drum
4.0- 4.4	--	--	--	--	--	--	--	8	--	10	-
4.5- 4.9	--	2	--	--	--	1	1	--	--	3	--
5.0- 5.4	--	17	22	--	--	1	--	8	1	13	8
5.5- 5.9	--	72	52	--	--	--	3	22	--	9	9
6.0- 6.4	--	95	64	--	--	--	6	30	--	12	29
6.5- 6.9	--	99	72	--	--	--	--	14	1	--	23
7.0- 7.4	--	68	172	--	--	--	1	33	1	--	11
7.5- 7.9	--	4	144	--	--	--	--	16	--	5	4
8.0- 8.4	--	6	277	--	--	--	--	15	--	3	19
8.5- 8.9	--	4	107	1	--	--	--	4	--	6	13
9.0- 9.4	--	22	110	3	1	--	--	8	--	20	55
9.5- 9.9	--	4	101	--	--	--	--	6	--	15	18
10.0-10.4	--	8	132	--	--	--	--	3	--	30	11
10.5-10.9	--	11	35	2	--	--	--	1	--	3	5
11.0-11.4	--	6	24	3	--	--	--	--	--	3	3
11.5-11.9	--	3	18	2	--	--	--	--	--	10	2
12.0-12.9	--	--	22	3	--	--	--	--	--	6	8
13.0-13.9	1	18	--	17	--	--	--	--	--	5	6
14.0-14.9	--	109	--	21	--	--	--	--	--	--	9
15.0-15.9	2	135	--	17	--	--	--	--	--	--	9
16.0-16.9	2	24	--	22	--	--	--	--	--	--	19
17.0-17.9	1	2	--	15	1	--	--	--	--	--	7
18.0-18.9	1	--	--	11	--	--	--	--	--	--	10
19.0-19.9	3	--	--	18	--	--	--	--	--	--	5
20.0-20.9	8	--	--	5	--	--	--	--	--	--	4
21.0-21.9	6	--	--	6	--	--	--	--	--	--	--
22.0-22.9	10	--	--	6	--	--	--	--	--	--	2
23.0-23.9	10	--	--	2	--	--	--	--	--	--	--
24.0-24.9	3	--	--	1	--	--	--	--	--	--	--
25.0-25.9	2	--	--	--	--	--	--	--	--	--	--
26.0-26.9	1	--	--	--	--	--	--	--	--	--	--
27.0-27.9	2	--	--	1	--	--	--	--	--	--	--
28.0-28.9	2	--	--	--	--	--	--	--	--	--	--
29.0-29.9	--	--	--	--	--	--	--	--	--	--	--
30.0-30.9	--	--	--	--	--	--	--	--	--	--	--
31.0-31.9	--	--	--	--	--	--	--	--	--	--	--
32.0-32.9	--	--	--	--	--	--	--	--	--	--	--
33.0-33.9	--	--	--	--	--	--	--	--	--	--	--
34.0-34.9	1	--	--	--	--	--	--	--	--	--	--
35.0-35.9	1	--	--	--	--	--	--	--	--	--	--
36.0-36.9	--	--	--	--	--	--	--	--	--	--	--
	56	709	1,352	156	2	2	11	168	3	153	289

a/ Survey conducted by personnel of the Minnesota Department of Natural Resources.
Source: Minnesota Division of Game and Fish, "Fisheries Lake Survey-Big Stone Lake," June 17-September 17, 1971.

TABLE 15

LENGTH - FREQUENCY DISTRIBUTION OF FISHES COLLECTED WITH A PULSATING DC ELECTROSHOCKER FROM BIG STONE LAKE, MINNESOTA, JULY 12-14, 1971
(Data Collected by Personnel of the Minnesota Department of Natural Resources)

Total Length (in.)	Species and Number of Fish in Length Groups									
	Bigmouth Buffalo	Quillback	White Sucker	Carp	Stoneroller	Common Shiner	Emerald Shiner	Bluntnose Minnow	Black Bullhead	Brown Bullhead
YY					1[a/]		27[a/]	1[a/]		
3.0-3.4										
3.5-3.9										
4.0-4.4										
4.5-4.9									1	
5.0-5.4										
5.5-5.9						1				
6.0-6.4										
6.5-6.9										
7.0-7.4										
7.5-7.9										
8.0-8.4									1	
8.5-8.9										
9.0-9.4										
9.5-9.9										
10.0-10.4										
10.5-10.9										
11.0-11.4										
11.5-11.9										1
12.0-12.9									3	1
13.0-13.9									2	1
14.0-14.9		1								
15.0-15.9										
16.0-16.9										
17.0-17.9										
18.0-18.9			1							
19.0-19.9										
20.0-20.9										
21.0-21.9										
22.0-22.9				1						
23.0-23.9	1									
24.0-24.9				3						
25.0-25.9				6						
26.0-26.9				5						
27.0-27.9				5						
28.0-28.9				6						
29.0-29.9				2						
30.0-30.9				1						
31.0-31.9				2						
32.0-32.9				4						
33.0-33.9										
34.0-34.9										
35.0-35.9				1						
Totals	1	1	1	36	1	1	27	1	7	3
% of Samples	0.46	0.46	0.46	16.59	0.46	0.46	12.45	0.46	3.23	1.38

TABLE 15 (Concluded)

Total Length (in.)	Northern Pike	White Bass	Yellow Perch	Walleye	Largemouth Bass	Pumpkinseed	Bluegill	Black Crappie	Freshwater Drum	Total (all species)
	Species and Number of Fish in Length Groups									
YY		13	61		1			6	1	
3.0-3.4										
3.5-3.9										
4.0-4.4			2							
4.5-4.9			7							
5.0-5.4			2							
5.5-5.9			2			1	1			
6.0-6.4		2	2				3			
6.5-6.9		6	2				1			
7.0-7.4		1	6							
7.5-7.9		5					1			
7.0-8.4		1								
8.5-8.9										
9.0-9.4										
9.5-9.9			1							
10.0-10.4				1						
10.5-10.9										
11.0-11.4		1								
11.5-11.9			1							
12.0-12.9		1								
13.0-13.9		1								
14.0-14.5		2								
15.0-15.9		2								
16.0-16.9					1					
17.0-17.9				1						
18.0-18.9										
19.0-19.9										
20.0-20.9										
21.0-21.9										
22.0-22.9										
23.0-23.9	1									
24.0-24.9										
25.0-25.9										
26.0-26.9										
27.0-27.9										
28.0-28.9										
29.0-29.9										
30.0-30.9										
31.0-31.9										
32.0-32.9										
33.0-33.9										
34.0-34.9										
35.0-35.9										
Totals	1	35	84	2	2	6	6	6	1	217
% of Samples	0.46	16.14	38.71	0.92	0.92	0.46	2.76	2.76	0.46	100

a/ Adult fish no length taken.
Source: Minnesota Division of Game and Fish, Fisheries Lake Survey - Big Stone Lake, June 17-September 17, 1971.

Yellow perch remain as the most abundant species and white bass as the third most abundant. Black bullheads, in this case, rank fifth in abundance. These discrepancies are due to gear selectivity.

By combining information from these three tables and looking at the commercial fish harvest (Table 3) it is apparent that yellow perch are probably the most abundant fish in the lake. Black bullheads probably rank a close second in abundance with white bass and carp ranking third and fourth, respectively. All of these species are either prolific spawners, omnivorous feeders, or both. To better understand population dynamics and project future trends for Big Stone Lake each of the important species are discussed separately in the following paragraphs.

Yellow perch: This species spawns from April 15 to early May when water temperatures reach 44-54°F. Spawning takes place in the shallows near rooted vegetation, submerged brush, or fallen trees, and at times over sand and gravel.[51/] The egg mass may be up to 7 ft in length and contain 2,000-90,000 eggs with an average of about 23,000.[51/] The egg masses are semibouyant and undulate with water movements while adhering to submerged vegetation or the lake bottom. They can thus be easily cast ashore and destroyed by wind, waves, and current.[51/] Reproductive seining in Big Stone Lake (Table 16) indicates that young-of-the-year perch tend to concentrate in the lower end of the lake. This may indicate that most of the spawning takes place downstream from the Hartford Beach area.

Yellow perch are gregarious and generally swim in large, compact schools. Food changes with season and size of fish, but generally consists of a wide variety of immature insects, invertebrates, and fishes.[51/] Growth is extremely variable depending on population size, habitat size, and lake productivity. When compared with the statewide averages, growth at Big Stone Lake is good, despite the large population size (see number per net, pounds per net, and average weight in Tables 12 and 13). At the end of 3 years of life, average total length is 9.2 in. (Table 17), compared to Age III lengths of 8.5 in. in Lake Erie, 6.0 in. in Lake Michigan, and 6.3 in. in Minnesota given by Coots.[52/]

This species is preyed upon by almost all other warm to cool water predatory fishes, including bass, sunfishes, crappies, walleye, other yellow perch, and northern pike.[51/] It is also preyed on by a number of species of birds such as gulls, mergansers, loons, and kingfishers.[51/] Thus its mere presence in such large numbers is indicative of a small predator population and its good growth rate is a direct result of the lake's high basic fertility. On many occasions stunting results from the high reproductive potential and voracious appetite of this species.[51/]

TABLE 16

NATURAL REPRODUCTION OF FISH AT BIG STONE LAKE, MINNESOTA

(Survey Conducted by Personnel of the Minnesota Department of Natural Resources Using Seines Measuring 40 Ft in Length and 4 Ft Deep with 1/4-In. Mesh. Samples Were Collected in Shoal Water Areas During the Period July 21-23, 1971)

Station Location	Beach in Ortonville		Ortonville Landing		0.5 Mile North of Big Stone City		The Peninsula		Across From No. 4		Kite Island		Minnesota by Kite Island		Manhatten Island		Rearing Pond		122N-47W-15	
Total Linear Distance Covered (ft)	20		25		30		30		25		50		50		50		50		70	
Greatest Water Depth (ft)	4		3		4		4		3.5		3		3		3.5		3		4	
Bottom Soil Type	Gravel		Cement		Gravel		Boulders		Boulders		Sand		Muck		Gravel		Rubble		Gravel	
Amount of Vegetation[a/]	None		Heavy		None		Moderate		None		None		Moderate		None		Light		None	
Water Temperature (°F)	80°		80°		80°		80°		80°		80°		80°		80°		75°		75°	
Wind Intensity[b/]	Calm		Calm		Calm		Calm		Calm		Calm		Calm		Calm		Calm		Calm	
Time of Day (military) and Date	1245, 7-21		1315, 7-21		1330, 7-21		1400, 7-21		1420, 7-21		1440, 7-21		1515, 7-21		1530, 7-21		0920, 7-22		1000, 7-22	
Species	YY[c/]	0[d/]	YY	0	YY	0	YY	0	YY	0	YY	0	YY	0	YY	0	YY	0	YY	0
Walleye																	1	0		
Northern Pike																				
Largemouth Bass							2	0	1	0			4	0	0	1	3	0		
Crappies	3	0			100	1	100	0	0	1							135	0		
Bluegills	1	0													0	1				
Orangespotted Sunfish			0	1																
Yellow Perch	4	0	1	0	100	7			2	1	0	3			0	6	71	0		
Bullheads							10,000	0	1	0	1	0	23	0			24	0		
White Bass	25	0	18	0			100	0	69	0	2	0	1	0	0	15	60	0	0	50
Freshwater Drum																				
Quillback													3	0						
Carp							1	0												
Shorthead Redhorse																			0	1
Common Shiner																	0	2		
Spottail Shiner																	0	1		
Emerald Shiner																	0	1		
Lake Chub																				
Fathead Minnow																				
Bluntnose Minnow							0	1									0	4		
Johnny Darter			0	3							0	1								
Iowa Darter	0	1																		
White Sucker																				

TABLE 16 (Continued)

Station Location	Meadowbrook		Meadowbrook		122N-47W-13		122N-47W-9		122N-47W-8		122N-47W-5		Milbank Landing		Southeast of Snapper Bay		Snapper Point		East of Easter Lodge		Hartford Beach		Foster Lodge	
Total Linear Distance Covered (ft)	80		50		60		50		20		75		100		50		50		50		75		50	
Greatest Water Depth (ft)	3.5		4		3.5		4		4		3		4		4		3.5		3		3.5		3	
Bottom Soil Type	Gravel		Rubble		Boulders		Gravel		Muck		Sand		Gravel		Gravel		Sand		Muck		Sand		Muck	
Amount of Vegetation[a/]	None		None		None		None		None		None		None		None		None		None		None		Light	
Water Temperature (°F)	75°		75°		75°		75°		75°		75°		75°		76°		75°		75°		75°		75°	
Wind Intensity[b/]	Calm		Calm		Calm		Calm		Calm		Calm		Calm		Calm		Calm		Calm		Light		Light	
Time of Day (military) and Date	1025, 7-22		1045, 7-22		1110, 7-22		1120, 7-22		1320, 7-22		1330, 7-22		1410, 7-22		1450, 7-22		1510, 7-22		1530, 7-22		0910, 7-23		0925, 7-23	
Species	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O
Walleye							7	0			21	0												
Northern Pike																								
Largemouth Bass			1	0	3	0									1	0								
Crappies	6	0	30	0	14	0	250	0			100	0			230	0	0	1	100	0			25	0
Bluegills							0	1																
Orangespotted Sunfish					0	1																		
Yellow Perch			170	0			750	1			96	5			20	2	1	0	100	0	18	0	51	0
Bullheads															1	0			5,000	0			1	0
White Bass	3	0	87	0			4,000	0			104	0	0	152	40	0	36	0	100	0	110	0	23	0
Freshwater Drum					1	0									1	0								
Quillback															1	0								
Carp																								
Shorthead Redhorse																								
Common Shiner																					0	1	0	1
Spottail Shiner	0	8	0	3	0	1			0	4	0	10			0	1			0	1	0	66	0	16
Emerald Shiner			0	10	0	1	0	25			0	18			0	6			0	2	0	1		
Lake Chub							0	3																
Fathead Minnow							0	1																
Bluntnose Minnow	0	1	0	5	0	3											0	1					0	1
Johnny Darter	0	8							0	1					0	3							0	5
Iowa Darter																								
White Sucker																								

TABLE 16 (Concluded)

Station Location	North of Hartford Beach		Bonanza		123N-49W-13		Yankeetown		Across from No. 26		Horstein Landing		Randell Farm South Dakota		North End		North End		Totals		
Total Linear Distance Covered (ft)	50		75		100		70		80		40		75		20		100		60,840 ft^2		
Greatest Water Depth (ft)	3.5		3		3.5		3.5		3.5		3		3		3.5		3.5		1.58 acres		
Bottom Soil Type	Rubble		Gravel		Sand		Sand		Gravel		Boulder		Sand		Muck		Gravel				
Amount of Vegetation a/	None		None		None		None		None		Light		None		None		None				
Water Temperature (°F)	75°		76°		68°		68°		68°		68°		68°		68°		68°				
Wind Intensity b/	Light		Strong		Light		Moderate		Moderate		Moderate		Moderate		Moderate		Moderate				
Time of Day (military) and Date)	0945, 7-23		1400, 7-28		1005, 7-23		1015, 7-23		1020, 7-23		1050, 7-23		1115, 7-23		1200, 7-23		1225, 7-23				
Species	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	YY	O	All
Walleye																			29	0	29
Northern Pike																			0	0	0
Largemouth Bass	1	0																	16	1	17
Crappies					32	0	2	0					1	0					1,128	3	1,131
Bluegills																			1	2	3
Orangespotted Sunfish																			0	2	2
Yellow Perch	71	0					10	0											1,456	25	1,481
Bullheads																			15,051	0	15,051
White Bass	51	0					2	0											4,831	217	5,048
Freshwater Drum																			2	0	2
Quillback																			4	0	4
Carp																			1	0	1
Shorthead Redhorse	1	0																	1	1	2
Common Shiner																			0	4	4
Spottail Shiner	0	63			0	50	0	15	0	10			0	29			0	19	0	297	297
Emerald Shiner	0	7	0	2	0	30			0	509			0	4			0	1	0	617	617
Lake Chub																			0	3	3
Fathead Minnow																			0	1	1
Bluntnose Minnow																			0	16	16
Johnny Darter	0	1			0	2	0	5			0	1							0	30	30
Iowa Darter																			0	1	1
White Sucker	1	0																	1	0	1

a/ Heavy, moderately, light, none
b/ Strong, moderate, light, calm
c/ YY - Young-of-Year or fingerlings
d/ O - Others, includes yearlings and adults, minnows, and darters
Source: Minnesota Division of Game and Fish, Fisheries Lake Survey - Big Stone Lake, June 17-September 17, 1971.

TABLE 17

FISH AGE CLASS DISTRIBUTION AND GROWTH RATES FOR SELECTED SPECIES AT BIG STONE LAKE, MINNESOTA, JUNE 17-SEPTEMBER 17, 1971[a/]

Species	Number of Fish in Each Age Group (Calculated Mean Total Length in Inches at Time of Last Annulus Formation)					
	I	II	III	IV	V	VI
Bigmouth Buffalo				4[b/]		
Quillback	2[b/]	3[b/]	4[b/]	--	--	--
White Sucker	6 (7.4)	42 (12.1)	17 (15.6)	1[b/]	1[b/]	--
Shorthead Redhorse	1[b/]	11[b/]	29[b/]	24[b/]	11[b/]	2[b/]
Carp	16[b/]	3[b/]	2[b/]	14[b/]	33[b/]	14[b/]
Northern Pike	2[b/]	3[b/]	24 (20.9)	3[b/]	--	2[b/]
White Bass	69 (5.2)	23 (9.6)	21 (11.6)	24 (13.0)	10 (14.1)	1[b/]
Yellow Perch	52 (2.9)	68 (6.0)	44 (9.2)	2[b/]	2[b/]	1[b/]
Walleye	11 (6.9)	34 (12.5)	30 (15.8)	16 (18.0)	11 (19.7)	2[b/]
Pumpkinseed	2[b/]	8 (3.9)	1[b/]	--	--	--
Bluegill	6 (2.1)	39 (4.1)	44 (6.8)	7 (8.4)	2[b/]	--
Black Crappie	35 (2.2)	11 (5.8)	41 (8.6)	8 (10.6)	11 (11.2)	2[b/]
Freshwater Drum	53 (4.9)	20 (9.4)	10 (11.9)	22 (14.2)	12 (15.8)	8 (17.1)

a/ Survey conducted by personnel of the Minnesota Department of Natural Resources.
b/ Data not available on length at last annulus formation.

The future of yellow perch in Big Stone Lake appears to be bright if current management continues. At this point, the major factor which could upset the balance of this population is the occurrence of a large fish kill related to over enrichment of the lake and the resultant oxygen depletion.

Black bullhead: Spawning takes place in early summer. Usually about 200 eggs are laid, but the ovaries contain 3,000-4,000 prior to spawning.[51] Eggs are deposited in a nest in areas of moderate to heavy submerged vegetation.[51] Newly hatched young school in a loose sphere and are guarded by the parent for several weeks. Soon after the size of the young exceed 1 in. the parents abandon them.[51]

Growth is extremely variable year to year and place to place. Stunting may occur due to overcrowding and a maximum size of 12.4 in. at Age IV is indicated.[51] Food items include immature insects, clams, snails, crustaceans, plant material, leeches, and fishes. They are competitors of sunfishes and some other bottom feeders.[51]

The habitat occupied by this species is usually low gradient small to medium-sized streams, backwaters of large rivers, ponds, and silty, soft bottomed areas of lakes or impoundments. It does not usually occupy the areas typical of brown and yellow bullheads, but seems to replace these species where the habitat deteriorates or pollution increases.[51]

Predation on the black bullhead is low, even during the younger life stages. This may be partially due to their habitat, the type of fishes associated with them, protection afforded by their spines, or their nocturnal habits.[51] The future of quality fishing for this species at Big Stone Lake does not look bright. Data presented in Tables 12 and 13 tend to indicate that this species is beginning to over-populate the lake. Average size is considerably less than the statewide average, despite a considerable commercial harvest (Table 3).

White bass: This species spawns in early spring over shoals or in tributary streams in depths ranging from 2-12 ft.[53] Sexually mature fish form schools, often unisexual in nature, before moving into the spawning areas.[51] During the spawning act several males surround a female and the group swims about rapidly and erratically while the female scatters demersal eggs at or near the surface. The eggs are fertilized as they sink and due to their adhesive nature stick to gravel, rocks, and vegetation.[53] The number of eggs produced averages 565,000 but may vary from 242,000-933,000.[54] This species is especially vulnerable to angling during the spawning act, and is easily taken with a variety of artificial lures.

The white bass is a gregarious species through all life stages and spends most of its time near the surface, even when in deep water.[51] Their food habits are carnivorous in nature. The younger fish feed on microscopic crustaceans, insect larvae, and fishes. As larger sizes are attained fishes become increasingly important in the diet, especially the yellow perch.[51] Growth at latitudes comparable to Big Stone Lake varies from 4.7-5.3 in. total length at Age I.[51] Comparing this to data presented in Table 17 this species is doing very well in Big Stone Lake, probably due to the abundance of yellow perch. Shoal seining (Table 16) tends to indicate the close association of this species with the yellow perch.

Carp: Carp also spawn in the spring and early summer. As the waters warm, adults move into weedy or grassy shallows, often in large numbers. Usually two or three males accompany a female during the spawning act and frantically thrash and splash about as the eggs are expelled at random adhering to submerged weeds, grasses, and roots.[51] This species is very prolific and may expel from 36,000-2,208,000 eggs.[55]

Growth is dependent on food availability and temperature.[51] Average weight for carp at Big Stone Lake is much higher than the statewide average (Tables 12 and 13), indicating a thriving population not yet reaching carrying capacity. The large commercial harvest (Table 3) is probably largely responsible for keeping this population under control. The basic food of this species is bottom fauna, primarily chironomids, zooplankton, phytoplankton, and plant remains.[56] They are notorious for stirring up bottom sediments during their feeding activities, but also are known to feed directly off the surface on floating organic debris.

Carp thrive in eutrophic waters;[57] they tolerate very low oxygen levels and extreme variations in temperature and pollution,[58] and tolerate turbidities far above those usually found in natural waters.[45] Their future in Big Stone Lake is, unfortunately, very bright if current trends toward accelerated eutrophication continue. Young-of-the-year carp are utilized by a number of predaceous fishes and birds.[51] Personal experience in Missouri (unpublished) has indicated that carp populations in small lakes can be controlled through proper predator management. However, growth of young carp in Big Stone Lake is very rapid and the predator population is too low to fully utilize the carp before large sizes are achieved. Thus, in order to control the carp in Big Stone Lake, it appears that further eutrophication should be controlled, commercial harvest maintained, and strict regulations on large predator removal adequately enforced.

Walleye: In terms of abundance (Tables 12 and 13) this species is second to the white bass in importance as a predator in Big Stone Lake. Spawning occurs in the spring and early summer. Spawning grounds are usually the rocky areas in white water below impassable falls and dams in rivers, or boulder to coarse-gravel shoals of lakes.[51] Spawning takes place at night in groups of one large female and one or two smaller males or two females and up to six males. Eggs and sperm are expelled in shallow water and fall into crevices in the substrate.[51] Walleye prefer to spawn over rock or gravel shoals; however, when unavailable, they will spawn over sand or silt bottoms. Egg survival on the latter type substrate is extremely low.[59] Numbers of eggs per female may be as high as 612,000.[51] No large spawning runs for this species are known for the tributary streams of Big Stone Lake.[38] Apparently, most of the spawning activities of this species are conducted in the shoal water areas within the lake. It is likely that due to the eutrophic condition of the lake dissolved oxygen levels in the thin microlayer adjacent to the substrate where the walleye eggs lie are extremely low. This usually results in high egg mortality and low natural recruitment. It is necessary for the Minnesota and South Dakota Natural Resource Departments to stock this species to maintain it as a viable population in the lake. Since 1966 (Table 11) over 10.5 million walleye fry and over 600,000 fingerlings have been released into Big Stone Lake by the two states.

Young walleyes feed extensively on cladocera and insects; and, after they reach a length of about 2 in. begin to add small fishes to their diet.[60] Adult walleye consume large quantities of fish, often feeding upon them almost exclusively. Yellow perch comprise a substantial part of their diet in Iowa, with suckers and bluegill following in abundance.[60] Under normal conditions walleye reach a length of 3-6 in. at Age I in northern Iowa.[60] Average length at Age I (6.9 in.) in Big Stone Lake (Table 17) compares favorably. This is probably due to the abundance of yellow perch for forage and lack of both inter- and intraspecific competition from large numbers of other predators.

The future of the walleye in Big Stone Lake seems to be largely dependent on artificial propagation and stocking; and, will remain so unless something is done on a large scale to improve habitat conditions in the lake.

Northern pike: The northern pike and walleye are the most desirable species to sport fishermen in northeast South Dakota.[61] Unfortunately, their combined numbers in the total fish population of Big Stone Lake, at best, totals less than 4% of the population.

However, unlike the walleye, large spawning runs of northern pike are known in the Little Minnesota River and Fish Creek.[38] Spawning of this species takes place in early spring immediately after the ice goes out.[51] A large female usually accompanied by several males much smaller in size moves into the shallow inlets and marshy areas of lakes and streams to complete the spawning act. The adhesive eggs are deposited over the bottom or on submerged vegetation.[60] Numbers of eggs produced by each female varies with her size. It has been estimated that the average female will produce 9,000 eggs per pound of body weight.[51]

At hatching, the young are 0.2-0.3 in. long. They remain inactive for 6-10 days and feed on the stored yolk.[51] They are often attached to vegetation by means of adhesive glands on their head. After the yolk is absorbed, young pike feed heavily on zooplankton and some immature aquatic insects for 7-10 days. The eggs and young of northern pike fall prey to a wide variety of predators, including other fishes (minnows, perch, and other northern pike), the large larvae of various aquatic insects, waterfowl, diving birds, and aquatic mammals.[51] Mortality to Age I has been estimated as high as 99%.[56]

By the time the young reach 2 in. in length, small fish become the predominant food item.[51] Adult pike can best be classed as omnivorous carnivores that eat virtually any available living vertebrate that is small enough to engulf.[51] Depending on food availability and habitat, young pike may reach lengths up to 15 in. at the end of their first year of life. Growth at Big Stone Lake appears to be good when comparing average weights of specimens in the 1971 survey with statewide averages (Tables 12 and 13).

The habitat of pike is usually clear, warm, slow, meandering, heavily vegetated rivers, or warm weedy bogs of lakes.[51] They are generally sedentary in nature, establishing a vague territory where cover and food are adequate. In the spring and fall they occur in shallow water but retreat to deeper water with rising summer temperatures.[51]

The future for this species in Big Stone Lake may be threatened if accelerated eutrophication continues. Presently, the population size is probably a little below average for Minnesota Lakes (see Tables 12 and 13, numbers per net). Carlander suggests that Minnesota Lakes average one pike per 0.67-0.91 surface acres of water.[56] Stocking has also been necessary to maintain good numbers of this species in the lake, despite the known occurence of large spawning runs. Since 1966, over 17,000 fingerlings, 1,800 yearlings, and 200 adults (Table 11) have been released in the lake by the two states.

Largemouth bass: This species is one of the top game fish in most parts of the United States. However, in northeast South Dakota it is preferred by only 3.0% of the anglers interviewed;[61] possibly because it apparently does not do well in the natural lakes and streams in this locality, and therefore, is not plentiful (Tables 12 and 15). Some suitable spawning habitat is available in the Peninsula Bay area and between the islands on the South Dakota shore; however, populations and spawning success has been low for a number of years.[38] This species has been stocked in recent years (Table 11) and was stocked as early as the 1940's.[43] However, unless this is continued for several years on a very large scale and cover in the form of submerged brush and logs is increased, it is doubtful that the effects will be permanently appreciated.

Bluegill: Bluegill and black crappie rank as the top two species of sunfish in Big Stone Lake (Tables 12, 13, and 15). Bluegill fishing in 1971 was described as the best in several years but the total population was low.[38]

Bluegill spawning occurs in the spring and may recur two additional times before fall. Nests may be built on substrates of sand, gravel, or mud in shallow water. Nesting is usually colonial with up to 30 nests crowded in 160 sq ft of suitable territory.[51] Growth is usually rapid in populations where crowding is not a problem. Average length at Age I in Big Stone Lake is 2 in. (Table 17). When compared to statewide averages, this species is nearly twice as large in Big Stone Lake (Tables 12 and 13).

The bluegill generally inhabit shallow, weedy, warm-water lakes and ponds, as well as slow flowing areas of small creeks and rivers.[51] They are preyed upon at all ages by a wide variety of predators. The factor limiting population growth in Big Stone Lake is possibly a lack of sufficient spawning areas. This may be directly related to habitat destruction by the large rough fish population. The bluegill population will thus probably not improve in the near future.

Black crappie: The closest relative of this species, the white crappie, is also found in Big Stone Lake. It seems unusual that the black crappie is more abundant since its tolerance to silt turbidity is generally considered to be less than that of the white.[60]

Both species build nests and spawn in early spring.[51] Spawning substrates usually consist of sand, gravel, or mud where there is some vegetation.[51] Unpublished data for small Missouri lakes indicate that populations of these species tend to be cyclic where they occur together (i.e., one species or the other dominates the catch in alternating years). This is apparently not the case for Big Stone Lake according to 1963-65 trawling data (Table 18).

TABLE 18

BIG STONE LAKE TRAWLING SUMMARY
1963 - 1964 - 1965
MINNESOTA 24 FT TRAWL DATA ONLY

Year	1963		1964		1965	
Date	July 16-18		July 20-21		August 17	
No. Hauls	14		11		10	
Time	98 min		75 min		70 min	
Species	No/Haul		No/Haul		No/Haul	
	YY	Adult	YY	Adult	YY	Adult
Northern Pike	0.2	--	--	--	--	--
Walleye	0.1	0.7[a]	0.9	0.9	0.1	0.6
Perch	0.1	35.6	6.1	58.0	5.9	18.3
White Bass	3.8	0.3	--	11.7	38.4	3.6
Freshwater Drum	0.5	10.6	43.5	27.7	13.0	6.5
Black Crappie	0.9	7.1	3.3	5.2	12.7	4.8
Bullhead	0.1	3.9	--	35.6	--	37.0
White Sucker	--	0.2	--	1.2	--	0.1
Carp	0.2	0.2	--	1.0	--	0.3
Northern Redhorse	--	0.1	--	--	--	--
Bigmouth Buffalo	--	--	--	--	--	0.1
Total	5.9	58.7	53.8	141.3	70.1	71.3

a/Yearling
Source: Minnesota Department of Natural Resources

Young crappie feed on small invertebrates until approximately Age III, then the diet shifts to a wide variety of small fishes.[51/] Feeding activity is usually not directly associated with the shoreline, but conducted in open water. Growth depends on the amount and productivity of suitable habitat.[51/] Data presented in Tables 12 and 13 indicate that this species is about average in abundance and size for other Minnesota lakes (see numbers per net and average weights).

Reproductive seining (Table 16) indicates that this species is probably spawning at scattered points throughout the lake, and for the most part, the population in Big Stone Lake will probably remain stable in the foreseeable future.

Freshwater drum (Sheepshead): This species is primarily a commercial rather than a sport fish and it is usually caught only incidentally by anglers. Its significance in this report lies primarily in its decreasing abundance in the commercial catch at Big Stone Lake (Table 3).

Unfortunately, little is known about its spawning requirements, except that it probably spawns over sand and mud bottoms at a depth of about 6 ft.[51/] Also, the eggs are bouyant and are carried by the currents which may explain the extremely wide range of the species.[51/] The drum generally inhabits large, shallow bodies of water and prefers clear water, but is able to adapt to relatively high turbidity levels.[51/] Unpublished data for oxbow lakes in Missouri indicated that size of year classes are extremely variable and may be related to environmental conditions in these shallow lakes. Trawling data for 1963-65 at Big Stone Lake similarly show large year class variability (Table 18).

The drum is typically a bottom feeder eating entomostrocans and larger aquatic insects, as well as crayfish, mollusks, and fishes at later life stages.[51/] Growth data of Big Stone Lake compares favorably to that presented for Lake Erie.[51/] Average weight for this species (Tables 12 and 13) is about equal to Minnesota averages.

The future of this species in Big Stone Lake is questionable. It seems apparent at this time that commercial harvest has reduced the size of the breeding population. Commercial harvest (Table 3) tends to reflect year class abundance apparent from trawling data (Table 18), assuming that drum enter the commercial catch primarily at Ages II and III.

Bigmouth buffalo: This species, commonly considered a rough fish, does not appear to be abundant from fish population data presented in Tables 12, 13, and 15. However, it is important in the commercial catch (Table 3). This discrepancy is apparently again due to gear selectivity.

It spawns in early spring over mud bottoms in the marshy areas of small tributary streams and lake margins, usually at the onset of spring flooding.[51] Considerable splashing activity is associated with the spawning act. Up to 750,000 eggs have been estimated from a 26 in. female. Eggs are scattered and abandoned.[51]

Food organisms consist of plankton as well as bottom organisms. The species occupies a niche described as "overlapping bottom feeders and plankton feeders".[51] Lengths of 5-7 in. are achieved at Age I in Iowa.[60] Their gibbous body shape makes them difficult to swallow, so they have very few natural enemies even though they typically live among a variety of large predators.[51] Due to the unusual feeding habits the species is usually taken by man only with the bow and arrow or while gigging or snagging.

As a plankton feeder this species will probably benefit from the continued enrichment and associated algal blooms of the lake. It was not included on fish population lists prior to the 1971 survey (Table 7); however, its presence was apparent in commercial fishing data as early as 1960-61 (Table 3). Its introduction into the lake was probably accidental, but it will probably remain an important component of the fish population of Big Stone Lake for many years to come.

Lake Sturgeon: This species is considered rare in Minnesota, endangered in South Dakota, and threatened throughout the United States.[15,62] Early unconfirmed reports indicate that it once occurred in Big Stone Lake, and Bailey and Allum[39] suggest that it may still be found in the area.

This species spawns in the spring in shallow water yielding up to 667,000 eggs per female. However, it does not reach maturity until age 20 and females do not spawn every year.[15] Eggs are usually deposited at random and adhere to rocks and logs.[51] Depletion of this species was probably directly related to man's activities as previously discussed.

The usual habitat of the species is the productive shoal areas of lakes and rivers in water 15-30 ft deep. They are adapted to bottom feeding and are usually found over mud or gravel bottoms sucking up and consuming anything edible.[51] They reach lengths of 7-11 in. the first year of life and have few natural predators due to bony scutes found on the young and the large size reached by the adults.

Hornyhead chub: This species is considered rare in South Dakota,[62] and is known to occur in the Big Stone Lake area.[38,39] Spawning takes place in the spring in relatively shallow water, often

below a riffle. Nests are constructed of pebbles and stones by the male and several females may spawn in each nest. Each female may deposit a total of 1,000 eggs, a few at a time, in several nests.51/

Adults range from 4-6 in. in length and prefer clear, slow-moving, gravelly streams. Young are usually found in heavily vegetated areas.51/ The feeding habits are omnivorous and the species probably falls prey to a variety of predators.51/

Increased siltation and intermittent flow resulting from destruction of vegetative cover and intensive cultivation49/ may be responsible for the elimination of this species from parts of South Dakota.

Rosyface shiner: This species is considered rare in South Dakota62/ and has been found in Whetstone Creek.39/ Spawning occurs in early summer in shallow water over gravel at the side of a riffle.51/ Up to 1,400 eggs are deposited in a small depression in the gravel.51/

Adults range from 2-3 in. in length and the feeding habits are omnivorous.51/ They generally prefer flowing water over standing water and are usually found in the lower section of streams over fine gravel and sand.51/ They are also quite intolerant of high turbidity51/ which is probably the factor causing their gradual disappearance in South Dakota.

Blacknose dace: This species is also considered rare in South Dakota62/ and has also been collected in the Big Stone Lake region.39/ Spawning takes place in the spring over gravel bottoms of fast, shallow riffles. No nest is built and the species often prey on its own eggs.51/ Adults are usually less than 2.5 in. in length and fall prey to other fishes and fish-eating birds.51/ The food of the blacknose dace is mainly aquatic insect larvae.51/

They prefer small, clear, swiftly flowing streams.51/ Trautman suggests that gradient may be a factor in their distribution, noting that in Ohio areas originally occupied by this species had a relief of over 100 ft.57/

Golden redhorse: This species, considered rare in South Dakota,62/ has been previously collected from Whetstone Creek.39/ Spawning takes place in the spring over mainstream riffles rather than in the tributaries.51/ No nest is built and up to 25,000 eggs per female are scattered and abandoned.51/

Food consists entirely of invertebrates collected from the stream bottom.[51] Only the young are subjected to significant predation as adults reach lengths of 20 in.

In Missouri, it reaches its greatest abundance in moderately clear, unpolluted streams having large, permanent pools and well defined gravelly or rocky riffles.[49] There is some disagreement in the literature, but it seems likely that its decline in South Dakota may be attributed to a combination of domestic and agricultural pollution and localized semi-arid conditions.

Yellow bullhead: This species is considered rare in South Dakota,[62] but can be found in fair numbers in Big Stone Lake (Table 12). Spawning takes place in the spring and nests are built and young cared for in a fashion similar to the black bullhead. Up to 4,200 eggs may be deposited in a nest.[51]

Adult size may reach lengths of 18 in.[51] The species is a nocturnal, bottom feeder, and considered a scavenger. Food ranges from offal crustaceans to insect larvae, mollusks, and fishes.[51]

Preferred habitat is heavily vegetated, clear water parts of lake bays, small shallow lakes, and slow moving streams with bottom types ranging from muck to gravel.[51] According to Pflieger[49] the yellow bullhead prefers clearer water than the black bullhead. This may account for its failure to compete effectively with the black bullhead in Big Stone Lake.

Brown bullhead: This species is also considered rare in South Dakota[62] and is not found in large numbers in Big Stone Lake. This species may spawn more than once from early summer to early fall.[51] Nesting and care of young varies only slightly from the other bullheads, except that occasionally both sexes may eat some or all of the eggs. Up to 13,000 eggs may be deposited by a single female.[51]

This species may reach lengths of 20 in. but usually does not exceed 15 in. It is also a nocturnal, bottom feeder, utilizing a wide variety of plant and animal foods.[51] Young of the species fall prey to a wide variety of predators, including northern pike and walleye. This sometimes occurs out of proportion to their numbers relative to the availability of other forage fishes.[51]

Their habitat requirements are similar to those of the yellow bullhead, except that the brown bullhead occurs less frequently in flowing waters.[49] They also seem particularly resistant to domestic and industrial pollution.[51] Failure of the species to reach large proportions in Big Stone Lake may be related to the ease with which they fall to predation.

Blackside darter: This species is considered rare in South Dakota[62] and has also been collected in Whetstone Creek.[39] The blackside darter is a small fish that typically lives in quiet pools of medium-sized gravelly streams.[51] It is a spring spawner and up to 1,700 eggs are deposited in the gravel at the bottom of pools or raceways, but not in riffles.[51]

Adult size rarely exceed 3.6 in. and food items have been reported to consist of small crustaceans, insect larvae, and fish. Feeding activity is not restricted to the bottom, as with most darters, but may occur throughout the water column including the surface.[51] It tolerates moderate amounts of turbidity if there is enough current to keep the bottom mostly free of silt.[49] The reason for its disappearance from South Dakota is unknown.

Slenderhead darter: This species is also considered rare in South Dakota[62] and has been collected in Whetstone Creek.[38] It inhabits medium-sized creeks to large rivers that have moderately clear water and permanent flow. In these areas it is usually found on gravelly or rocky riffles in moderate to swift current.[49]

Spawning occurs in the spring in riffles over bottoms of rubble and gravel at depths of 18 in. or more.[63] It avoids silty or turbid streams[49] and this may account for its disappearance from South Dakota waters. Food items include insect larvae and fish eggs.[63]

In summarizing the condition of the fish population of Big Stone Lake it seems likely that game fish populations (especially in terms of large predators) will decline unless management efforts are maintained at full scale. This will be largely the result of continued habitat destruction by the growing rough fish population which itself is the result of accelerated eutrophication. Additionally, those species which are intolerant of silt turbidity will continue to decline in number.

The stream fish populations will probably decline in species diversity similar to those of the Upper Neosho River system after 15 years of heavy feedlot drainage.[64] Species such as the hornyhead chub, rosyface shiner, and yellow bullhead will probably be eliminated from the streams while species such as the creek chub, sand shiner, stoneroller, golden redhorse, shorthead redhorse, and slenderhead darter will probably decrease sharply in number.[64] Generally, bottom dwellers will decline in abundance while surface dwellers may increase.[64] Cross and Braasch[64] felt that most of those species which increased in number in the Neosho River system were those which attain large size, occur commonly in a downstream reservoir, and are vagile enough to disperse

rapidly through the river when conditions become tolerable after a fish kill. Examples of these species include the largemouth bass, walleye, and crappie.

B. Cultural Elements

The cultural factors in and around the Big Stone Lake Watershed area are discussed below in terms of archaeological sites, historical structures, sites, monuments, etc. and contemporary cultural activities (architectural works, festival and fair sites, ethnic colonies, etc.). Although these cultural elements are not discussed in great detail, sufficient information is presented to indicate courses of action to be taken in the follow-up or Phase II work to this preliminary study. In this regard, the steps to be taken to preserve important historical and archaeological data are discussed in Public Law 93-291, May 24, 1974. This act must be complied with by agencies responsible for environmental impact studies and statements on water resources projects under the National Environmental Policy Act (NEPA), 1969.

1. Archaeological factors: The archaeology of the watershed area probably dates back to the Cambrian Period and more recently prehistoric aboriginal Americans. Some 90 or more of these sites (burial mounds, villages, human remains, etc.) are believed to exist in the area, primarily along the east and west banks of Big Stone Lake.[79-81] Those sites which have been identified by the South Dakota and Minnesota Archaeological Societies are shown in Figure 3.

It is important to understand that once destroyed, the value of these sites is forever lost. Although there are no archaeological sites on the National Register, it is essential that future operations in the watershed avoid adversely impacting on known or suspected areas of archaeological importance.

2. Historical features: The modern history of the Big Stone Lake Watershed area is one of early exploration by foreign powers followed by the establishment of fur-trading activities. Keen competition in this enterprise developed in the 17th and 18th centuries between France and England. By the middle of the 1700's, British traders operating out of Hudson Bay had begun to overtake their French rivals who had dominated the scene since the explorations of La Sueur* (a fur trader from Montreal) in the 1600's.[82] As a result of the French and Indian War (1756-1763),

* It is suggested by some historians that La Sueur was the first white man in the area.

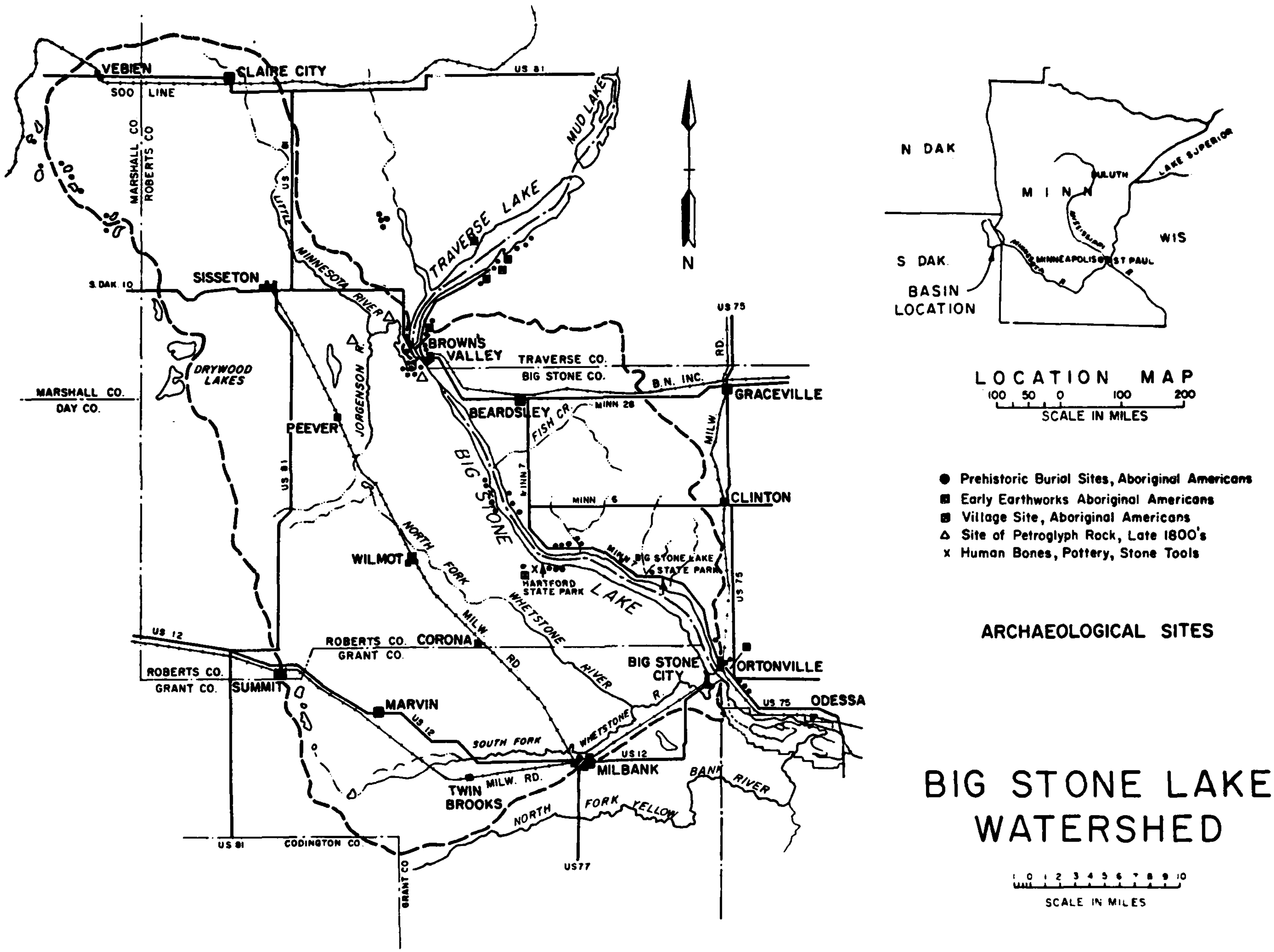

Figure 3 - Big Stone Lake Watershed - Archaeological Sites

France gave up essentially all claims to any rights in South Dakota and Minnesota, turning, thereby, these areas over to British control.

With the defeat of the British in the War for independence and again in the War of 1812, England's hold on American lands ended. At about the same time (1762) France made a secret deal with Spain in which the vast region west of the Mississippi was ceded to the Spanish. However, in 1800 the King of Spain retroceded the "Louisiana Territory", which included South Dakota and Minnesota, to France. Not relishing the thought of having Napoleon as a neighbor, in 1803 the United States purchased the a~ea from France (the Louisiana Purchase).

Between about 1800 and 1865 a number of trading posts were established along Big Stone Lake from the Hartford area north to Brown's Valley. The sites of several of these and the residences of the fur traders and storekeepers are shown in Figure 4. Probably the earliest post in the area was the Hudson Bay Post at Brown's Valley, established in 1800.[83/] The Hazen Mooers Post on the west bank of Big Stone Lake was established in 1819 and just west of there on the bluff above the lake was the Martin McLeod Post, established in 1843.[83/] One of the last trading posts in the area was that of Soloman Robar and Moses Moreau in 1862-65.

The first American expedition into what is now the Big Stone Lake Watershed was conducted by U.S. Army troops under Major Stephen H. Long in 1823. The expedition established camp near the Hazen Mooers Trading Post (see Figure 4) on July 22, 1823. Though the Long exploration left little in the way of historic sites, the information gathered was significant to the Webster-Ashburton Treaty of 1842. This expedition was followed by a scientific investigation led by John C. Fremont in 1838 during which the area was mapped including Traverse and Big Stone Lakes. By the late 1850's new settlers had come to western Minnesota and eastern South Dakota and the fur trading business and farming began to flourish along Big Stone Lake. Also, one of the greatest ranges for wild buffalo was in the Big Stone area. The country between Big Stone Lake and the James River was known as "buffalo republic".[82/] In 1865 Big Stone Lake was so low that the Indians rode their ponies across it searching for buffalo. The last buffalo hunt in the area occurred just west of Twin Brooks in 1879 (Figure 4).[82/]

In the spring of 1863, while pursuing the Sioux, General Sibley camped just west of the Little Minnesota River near Brown's Valley. The affairs of the Indians in this area were administered from a subagency of the Yellow Medicine Agency and this was located in the Minnesota River gulch, southwest of Brown's Valley. It was called the Lake Traverse Agency.

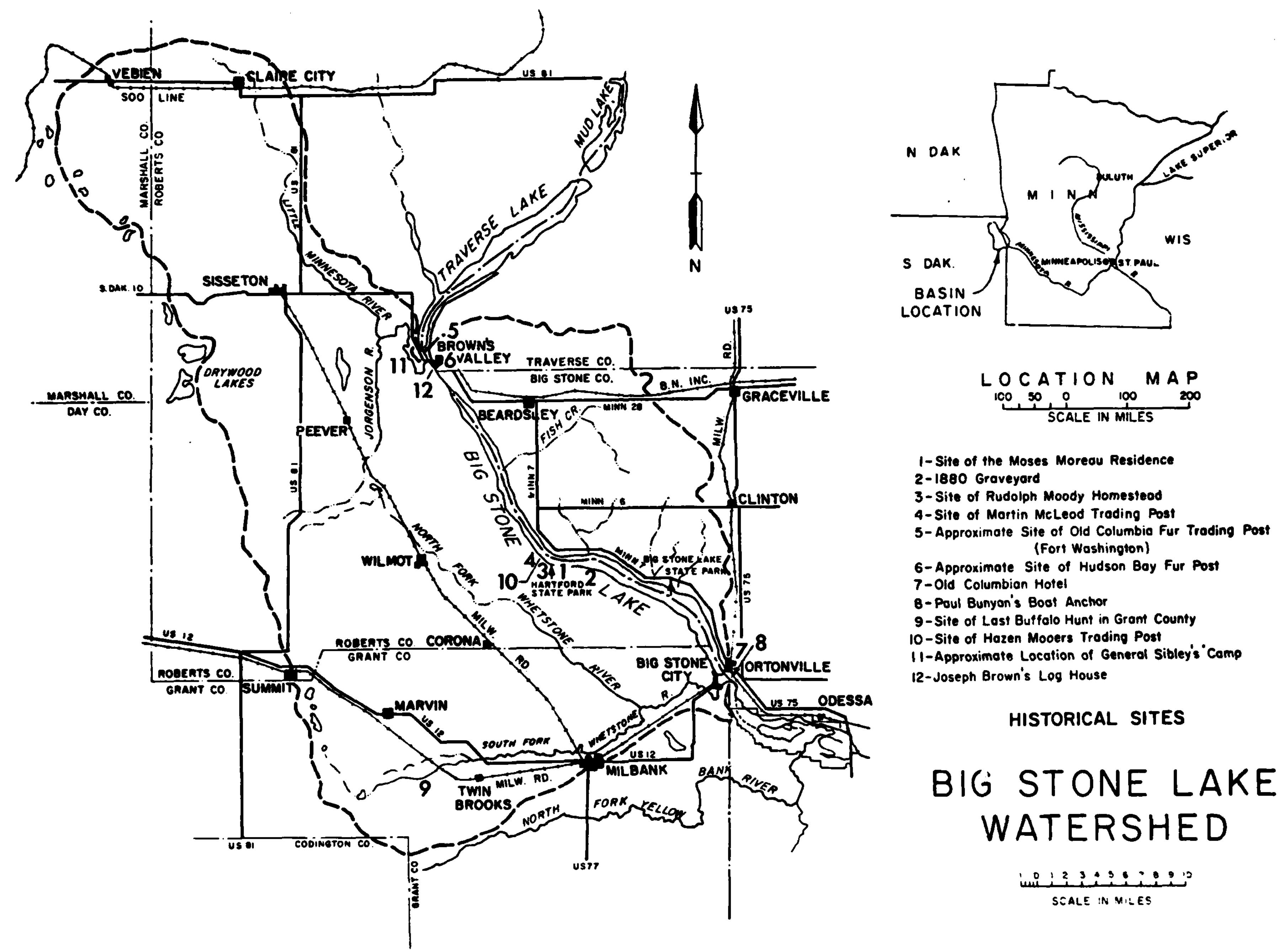

Figure 4 - Big Stone Lake Watershed - Historical Sites

Later, in 1870, it was moved to a site about 10 miles south of Sisseton and was known as the Sisseton Agency. Here were built substantial buildings of lumber and brick which were locally manufactured. A grist mill was also built. All that remains of the agency is the jail and a part of the administration building which was torn down in the summer of 1960.80/

As can be deduced from the above discussion, many sites, buildings, structures, etc., of historical importance exist in the Big Stone Watershed area.79-81/ However, to date there are no items of historical importance on either a State or National Register. While the State Historical Societies of both South Dakota and Minnesota are keenly interested in the history of the Big Stone Lake Watershed area, insufficient fund allocations have precluded the research necessary to include these sites on the National Register. Nevertheless, any future operations of the Corps of Engineers should carefully avoid tasks which might adversely affect the historical features of the area as discussed above and shown in Figure 4.

3. Contemporary cultural activities

a. Architectual and engineering works: The Big Stone Power Plant, looming above Big Stone Lake, is the primary engineering work currently in the area. Jointly owned by the Montana-Dakota Utilities Company, Northwestern Public Services Company, and the Otter Tail Power Company, the plant represents the largest single investment of private capital in the South Dakota area. The Big Stone Plant is the result of a decision, made in 1969, by the plant's present owners to cooperate in building one large, efficient unit to provide for the customer needs of all three companies. Perhaps the most important aspect of the plant is its emphasis on environmental safeguards. The construction of a 340-acre man-made lake to insure zero discharge of waste water and a cooling pond of 350 acres feed from a water intake structure on Big Stone Lake. Specially designed electrostatic precipitators that remove particulate matter from stack emissions are coupled with a unique coal-handling and transportation system that have initiated environmental safeguards necessary to the welfare of the surrounding areas. The plant begins operation in mid-1975 with a staff of approximately 55 employees.

b. Recreational activities and other cultural events: Corn Festival Day and Sam Brown Days are the primary culturally oriented events standing out within the Big Stone Lake area. The Corn Festival, held annually on Labor Day, brings together the Ortonville area people for a day of fun and festivity. Likewise, Sam Brown Days in Brown's Valley, fall annually during the last week in June, commemorating the founding of Brown's Valley.

Located in Brown's Valley is the historical Log House built in 1863 (see Figure 4) to house the headquarters of the head scout at Fort Wadsworth, Joseph R. Brown. As the name implies, Brown's Valley was named after Joseph R. Brown, and the Log House was kept as a historical reminder. The Log House was first used as a trading post and dwelling, then as a post office, and later again as a dwelling until its final disposition as a State Park and museum. Samuel J. Brown State Monument lies just outside Brown's Valley. Praising the historic ride of Sam Brown, the son of the city's founding father, the monument commemorates his heroic deed. Leaving at night, Sam Brown, often referred to as the frontier "Paul Revere", rode to alert scouts and others of a suspected Indian raid. Although his heroic ride went for naught, his heroic intentions are praised by the state monument.

Along the Big Stone Lake shore lies the Big Stone State Park in Minnesota and the Hartford Beach State Park on the South Dakota shore. Both parks provide a pleasant, natural habitat in which to relax and camp. Primarily attracting fishermen, the parks cater to campers and picnickers interested in recreational surroundings. Both areas are used primarily by fishermen.

Big Stone State Park in Minnesota covers 1,250 acres of land, consisting of two areas, Bonanza and Meadowbrook. In 1974 there were 16,000 campers utilizing the park. Its facilities include campgrounds with running water and sanitation facilities, a boat and landing area along with nature trails, and picnic areas.

The well-groomed Hartford Beach State Park in South Dakota covers 320 acres and has approximately 93,000 visitors per year of which 10,000 are campers. The park has limited itself to 50 overnight camping units. The visitors, like at Big Stone State Park, are mostly vacation returnees or those who have heard of the lake through friends or neighbors. Approximately 25% of the campers coming into the park are from other states, with about half from Minnesota. The park offers the visitor the opportunity to swim (if the algae content is not to dense), fish, and the use of picnic grounds with running water, sanitation facilities, electrical hookups, and the beach, docks, and nature trails.

Camp Tepeetonka, a YMCA camp located on an island 100 yd off the South Dakota shore, provides a unique camp on the lake. Within the last 5 years the camp has increased its enrollment from 950 campers to 1,500 campers. The campers come primarily from the Sioux Falls, South Dakota, area; however, a program to attract campers from other regions has begun. Water activities are an important aspect of the camp's overall program; however, present water conditions are causing rescheduling of water-related activities.

c. Ethnic colonies: The Sisseton and Wahpeton Indian Reservation has its eastern boundary on Lake Traverse, just above Brown's Valley. The area was created by the treaty of 1867 and set apart by Congress as the permanent home of the Sisseton and Wahpeton tribes of the Sioux Indian Nation. Since this area does not come into immediate contact with Big Stone Lake it is mentioned merely to identify its existence and heritage.

d. Other: A socioeconomic profile of the region is presented in greater detail in Section IV, D, Evaluation of Benefits.

C. Environmental Use or Management Areas

In order to gain perspective on the use of lands in the Big Stone Lake Watershed for wildlife, conservation, or recreation, a brief regional analysis will be presented which locates this area in the Upper Mississippi River Basin. Data for the principal watershed counties (Big Stone County, Minnesota, and Grant and Roberts counties, South Dakota) will be given followed by a description of those management areas which are located within the watershed boundaries. A description of possible future expansions or additions to the land conservation system will follow, concluded with a discussion of the relationship between water quality of Big Stone Lake and the recreational use of the watershed area.

Big Stone Lake Watershed is located in the northwest corner of the Minnesota River Plan Area of the Upper Mississippi River Basin.[84/] The Minnesota River Plan Area covers 15,902 sq miles in 24 counties; the Big Stone Lake Watershed includes 1,149 sq miles, primarily in three counties. A relatively low population of 442,657 people gives this plan area a density of 29 persons per sq mile, which is the third lowest density of the 16 planning areas of the Upper Mississippi River Basin. The Big Stone Lake Watershed is outside the 3-hr travel time zone of the nearest SMSA, located in Minneapolis-St. Paul. Hence, there is less immediate population pressure on public lands in this area relative to the greater river basin region and weekend and vacation uses rather than day-use activities in Big Stone Lake Watershed are of primary importance for recreationists from the Minneapolis-St. Paul area.

Major land uses in the Minnesota River Plan Area and a classification of existing recreational lands is given in Table 19. The Bureau of Outdoor Recreation (BOR) Classification System is generally used to describe land or water areas which have been designated for wildlife or recreational uses.[85/] Under this system, Class I lands are high density recreation areas, usually within or near population centers and managed exclusively for recreational purposes. Municipal parks are generally Class I areas. Class II lands are relatively accessible to population

TABLE 19

MINNESOTA RIVER PLANNING AREA OF THE UPPER MISSISSIPPI RIVER BASIN

Major Land Uses	Acres	Percent
Cropland and pastureland	9,277,000	87.7
Forest land	346,000	3.3
Urban and built-up	340,000	3.2
Other	617,000	5.8
Total	10,580,000	100.0
Land area	10,580,000	97.7
Water area	249,000	2.3
Total area	10,829,000	100.0

Recreational And Wildlife Land Ownership	Acres	Percent
Federal	109,833	51.2
State	65,152	30.4
County	27	0.0
City	1,721	0.8
Private	37,877	17.6
Total	214,610	100.0

Recreational and Wildlife Use Lands	Acres	Percent
Classes I and VI	1,886	0.9
Classes II and IV	48,477	22.6
Classes III and V	164,247	76.5
Total	214,610	100.0

Source: U.S. Department of the Interior, Bureau of Outdoor Recreation. "Upper Mississippi River Comprehensive Basin Study," VI, Appendix K, Recreation (1970).

centers and are general outdoor recreation areas, designed for extensive day, weekend, and vacation use. These areas are equipped with some man-made facilities, which may vary from simple to elaborate; included in this category are some state and county parks, wayside rest areas, public access points and private resorts. Class III areas are natural environment areas, usually larger and more remote than Class I or II areas, and designed for extensive weekend and vacation uses related to high environmental quality. Wildlife management and production areas, forests, and some state and county parks would be Class III areas. These three classes include nearly all the wildlife and recreational use lands in the Minnesota River Plan Area. Classes IV, V, and VI are outstanding natural areas, primitive areas, and historic or cultural sites, respectively.

From Table 19 it can be seen that cropland and pastureland comprise about 88% of the land use of the Minnesota River Plan Area. Of the total 10,829,000 acres, 214,610 acres or 2.0% are available for recreational and wildlife land uses. By way of comparison, in the Mississippi River Headwaters Plan Area (north of the Minnesota River) 12.4% of the land is in recreational use due to large forest preserves; in the Des Moines Plan Area (south of the Minnesota River) 0.9% of the land is in recreation.

Big Stone Lake Watershed includes parts of Big Stone and Traverse Counties, Minnesota, and Grant, Roberts, Marshall, and Codington counties, South Dakota. Most of the watershed is in Roberts, Grants, and Big Stone counties; however, approximately two-thirds of Robert County and one-fourth of Big Stone County comprise about three-fourths of the watershed area. Data on wildlife, conservation, and recreation lands in Roberts, Grant,[86/] and Big Stone[85/] counties are shown in Tables 20, 21, and 22.

It can be seen from Table 20 that the State of South Dakota owns 77% (23,000 acres) of the total 29,705 acres of wildlife and recreational use lands in Roberts and Grant counties. Meandered lake lands comprise 72% of these state-owned lands, and 56% of the total wildlife and recreational use lands in the two-county area. The meander lake lands are areas which were omitted from the earliest government surveys; hence, they were never opened for homestead and titles were never issued by the federal government. Today these lakes and lake beds total nearly 160,000 acres of state land; Roberts County alone has nearly 14,000 acres, which is the fifth largest portion among all the counties. Federal and state waterfowl and wildlife production areas total 11,940 acres, or 40% of the wildlife and recreational use lands in Roberts and Grant counties; parks, accesses, and private recreation areas constitute the remaining 4%.

In terms of state acreages, waterfowl production areas and meandered lakes in the two-county area each represent approximately 10% of the state's total. This is a significantly large proportion considering this

TABLE 20

WILDLIFE AND RECREATIONAL USE LANDS, ROBERTS AND GRANT COUNTIES, SOUTH DAKOTA

Ownership	Type of Area	Roberts (Acres)	Grant (Acres)	Total (Acres)	State (Acres)	% of State Area
Federal	Waterfowl Production Areas	3,952	2,203	6,155	65,607	9.4
	Class I	0	0	0	424	0.0
	Class II	0	0	0	21,602	0.0
	Class III	3,952	2,203	6,155	3,033,350 a/	0.2
	Class IV	0	0	0	246,695	0.0
	Class VI	0	0	--	39	0.0
	Subtotal	3,952	2,203	6,155	3,302,118	0.2
State	State Parks and Recreation Areas	729 (2) b/	0	729	87,269	0.8
	Lake Access Areas	(6)	(2)	(8)	(178)	(4.5)
	Meandered Lakes	13,854 (20)	2,719 (10)	16,573 (30)	159,823 (224)	10.4 (13.4
	Game Production Areas	4,789 (22)	996 (6)	5,785 (28)	132,363 (448)	4.4 (6.3)
	State Game Refuges	0	9 (1)	9 (1)	6,909 (17)	0.1 (5.9)
	Roadside Parks and Rest Areas	6 (2)	9 (3)	15 (5)	448 (54)	3.4 (9.3
	Class I	0	0	0	8	0.0
	Class II	226	9	235	7,987	2.9
	Class III	19,040	3,724	22,764	373,323	6.1
	Class IV	0	0	0	1,731	0.0
	Class V	0	0	0	3,245	0.0
	Class VI	1	0	1	59	1.7
	Subtotal	19,266	3,733	23,000	386,353	6.0
County	County Parks and Recreation Areas	0	0	0	1,610 (10)	0.0
	Class I	0	0	0	132	0.0
	Class II	0	0	0	1,208	0.0
	Class III	0	0	0	270	0.0
Municipal	Municipal Parks	104 (16)	120 (16)	224 (32)	13,245	1.7
	Class I	52	14	66	6,707	1.0
	Class II	15	76	91	4,318	2.1
	Class III	37	30	67	2,219	3.0
	Subtotal	104	120	224	13,245	1.7
Private	Dude Ranches	(1)	0	(1)	(16)	6.3
	Licensed Campgrounds	3 (1)	1 (1)	4 (2)	1,474 (133)	0.3 (1.5)
	Organizational Camps	238 (3)	0	238 (3)	2,559 (35)	9.3 (8.6)
	Ski Areas	(1)	(1)	(2)	(5)	(40.0)
	Golf Courses	40 (1)	45 (1)	85 (2)	4,997 (75)	1.7 (2.6)
	Class I	241 (5)	1 (3)	242 (3)	4,034 (370)	6.0 (0.8)
	Class II	40 (3)	45 (2)	85 (5)	4,997 (105)	1.7 (4.8)
	Subtotal	281 (8)	46 (5)	327 (8)	9,031 (475) c/	3.6 (1.7)
Total	Class I	293	15	308	11,488	2.7
	Class II	280	130	411	40,212	1.0
	Class III	23,029	5,957	28,986	3,409,170	0.9
	Class IV	0	0	0	248,426	0.0
	Class V	0	0	0	3,245	0.0
	Class VI	1	0	1	98	1.0
	Grand Total	23,603	6,102	29,705	3,712,441	0.8

a/ Class III federally owned lands in the state also include national parks, forests, grasslands, wildlife refuges, and land managed by the BLM, Corps of Engineers, and BOR. None of these types of areas are found in Roberts or Grant Counties.

b/ Numbers in parentheses designate number of areas.

c/ Includes trap ranges and private fish fee areas which area not found in Roberts or Grant Counties.

Source: South Dakota Department of Game, Fish, and Parks, "South Dakota Interim Outdoor Recreation Plan," May 1964.

TABLE 21

BIG STONE COUNTY LAND USE

	Acres	Percent of Total Area
Net Land Area	340,776	100.0
Water Area	19,187	5.6
Total Area	321,589	94.3
		Percent of Net Land Area
Incorporated	5,418	1.7
Unincorporated	316,171	98.3
Developed[a/]	21,059	6.5
Agricultural	295,112	91.8
Nonbuildable[b/]	22,210	6.9
Buildable	272,902	84.9

DEVELOPED ACREAGE BY CATEGORY

	Acres	Percent of Developed[a/] Land
Developed	21,059	100.0
Roads	7,467	35.5
Residences	269	1.3
Public and Semi-Public	256	1.2
Commercial	6	0.0
Industrial	48	0.2
Recreation		
Public	12,689[c/]	60.3
Private	324	1.5

Source: Consulting Services Corporation, "Comprehensive Plan, Big Stone County," January 1970.

a/ Includes all residential, both farm and nonfarm, as well as commercial, industrial, public, recreational, and highway uses.

b/ Indicates lands held as federal waterfowl production areas, poorly drained areas, and areas with steep slopes.

c/ Recreation acreage has increased by approximately 520 acres since this plan was completed.

TABLE 22

WILDLIFE AND RECREATIONAL USE LANDS
BIG STONE COUNTY, MINNESOTA

Ownership	Type of Area	Big Stone County (acres)	% of County Recreational Area	% of Total County Land
Federal	Waterfowl Production Areas	5,730	42	
	Subtotal	5,730	42	1.7
State	State Parks (Big Stone Lake)	1,250	9	
	Public Access Areas	23	0	
	Roadside Parks	3	0	
	Meandered Lakes	> 400 a/	3	
	Wildlife Management Areas	5,512	41	
	Subtotal	7,188	53	2.1
County	County Parks (Toque Lake)	147	1	
	Subtotal	147	1	0.0
Municipal	Municipal Parks, Schools	72	1	
	Golf Course (Ortonville)	148	1	
	Subtotal	220	2	0.1
Private	Resorts	314	2	
	Camp (YMCA)	5	0.0	
	Hunting Club	4	0.0	
	Subtotal	323	2.4	0.1
	Total	13,608 b/	100.0	4.0

Type of Area	No. Areas	Acres
Public		
Class I	27	224
Class II	30	1,358
Class III	64	11,626
Subtotal	121	> 13,005 c/
Private		
Resorts	11	213
Other	NA	110
Subtotal	--	323
Total	--	> 13,328

a/ Greater than 10 acres surface water.
b/ Includes land and water acreages.
c/ Does not include water acreages.
NA Not available.
Source: Consulting Services Corporation, "Comprehensive Plan, Big Stone County," January 1970.
Minnesota Department of Conservation, Bureau of Planning, "Minnesota Outdoor Recreation Plan, 1968," June 1969.

area is only 2.4% of the state's total land area. These types of land account for the large percentage of Class III areas (97.6%) in these counties.

Somewhat more information is available on Big Stone County, because of the county's 1970 Comprehensive Plan.[85] Table 21 shows county land use data taken from this plan. Land is classified as incorporated and unincorporated. There is very little commercial or industrial activity outside the incorporated areas, and that which exists is generally confined alongside highways. The unincorportated areas are classed into broad categories of "developed" and agricultural, with "developed" including all residential (both farm and nonfarm), commerical, industrial, public, recreational, and highway uses. It can be seen that 92.8% of the total county area, and 98.3% of the county land area is unincorporated. Agricultural uses account for 93.3% of the unincorporated area. Recreation accounts for the largest single percentage (62%) of the land considered "developed" in the unincorporated area, with 12,689 acres in public recreation and 324 acres in private recreation. Also shown in Table 21 are the relative acreages of buildable and nonbuildable land presently classed as agricultural: included in the nonbuildable classification are federal waterfowl production area easements, poorly drained areas, and lands with steep slopes. Nearly 7%, or 22,210 acres of the total agricultural acreage is in this nonbuildable category. According to the Comprehensive Plan, lands poorly drained and not capable of supporting crops should remain undrained and be used for waterfowl production or wildlife management. The nonbuildable acreage represents nearly twice the amount of land currently in wildlife and recreational uses in this county.

Table 22 lists wildlife and recreational use lands in Big Stone County. As was the case for the South Dakota Counties, federal and state wildlife areas are the primary recreational areas, constituting 84% of the total wildlife and recreational use lands of the county. Of the total county area of 334,080 acres, wildlife and recreational lands comprise 4.0%, or more than 13,328 acres. (Figures on total recreational acreages include water areas in Table 22, and only land areas in Table 21.) Class III lands are again the dominant type of area, comprising 87.8% of the public lands; Classes I and II equal 1.7% and 10.4%, respectively.

Table 23 summarizes the total recreation land available in Roberts and Grant counties and the total public lands in Big Stone County. Including private lands, the three-county area has approximately 43,033 acres of wildlife and recreational use lands.

TABLE 23

TOTAL RECREATION AND WILDLIFE LAND AVAILABLE, ROBERTS AND GRANT COUNTIES, SOUTH DAKOTA, AND PUBLIC LANDS IN BIG STONE COUNTY, MINNESOTA

	I	II	III	IV	V	VI	Total
Roberts	293	280	23,029	0	0	1	23,603
Grant	15	130	5,957	0	0	0	6,102
Big Stone	224	1,358	>11,423[a]	0	0	0	>13,005[a]
	532	1,768	>40,409[a]	0	0	1	>42,710[a]

a/ Some water acreages are approximate.
Sources: See references 85, 86, and 88.

A preliminary inventory of wildlife, recreation, and open space lands located within the boundaries of Big Stone Lake Watershed was obtained through use of county data and area maps. This information is presented in Table 24.[50] It can be seen that state and federal wildlife preserves and refuges constitute a significant majority (approximately 82%) of the wildlife and recreational use lands in the watershed. Big Stone Lake and Hartford Beach State Parks are the most important general recreation areas in the area; a further description of available facilities at these two parks is found in Table 25.[87] There were many private recreation areas (primarily resorts bordering Big Stone Lake) that were not included in this table because there was no specific locational and acreage data available for them; it is known, however, that at least 14 resorts and many private homes are located on the lake shore.[1] The map (Figure 5) summarizes wildlife and recreational areas in Big Stone Lake Watershed.

The lakeshore of Big Stone Lake is in itself one of the most important recreational resources of the watershed. According to the Minnesota Lakeshore Development Study,[90] there are 206 seasonal homes and 62 permanent homes along 30.1 miles of shoreline on the Minnesota side of the lake. All but one of the seasonal lakeshore homes and 61% of the permanent lakeshore homes in Big Stone County are located on Big Stone Lake. With 8.9 dwellings per mile of shoreline, this lake is much more densely developed than any other lake in Big Stone County; of the 12 county lakes surveyed (all 150 acres or more in size) the next more densely developed had only 1.2 dwellings per mile of shoreline. Similarly, there

TABLE 24

BIG STONE LAKE WATERSHED: PRELIMINARY LISTING OF WILDLIFE, CONSERVATION, AND RECREATION AREAS

Name of Area	County	Ownership	Acres
Parks			
Big Stone Lake State Park (plus access)	Big Stone	State	970
Hartford Beach State Park (plus access)	Roberts	State	320
Summary of Municipal Parks (Big Stone)	Big Stone	Municipalities	22
Brown's Valley Municipal Park	Traverse	Municipalities	3
Orton Roadside Park	Grant	State	5
Lake Albert Roadside Park	Grant	State	3
Traverse Roadside Park	Roberts	State	2
Summary of Municipal Parks (Roberts)	Roberts	Municipalities	12[a/]
Summary of Municipal Parks (Grant)	Grant	Municipalities	60[a/]
Total			1,397
Scenic Roads and Trails			
Big Stone Lake State Park Hiking Trails	Big Stone	State	7 (miles)
Hartford Beach State Park	Roberts	State	
Hiking Trails			2-1/2 (miles)
General Roads			2 (miles)
Total, Hiking Trails			9-1/2 (miles)
Wildlife Preserves and Refuges			
Federal Wildlife Production Areas	Big Stone	Federal	1,440[b/]
	Roberts	Federal	1,525 (18)[c/]
	Grant	Federal	444 (7)
	Marshall	Federal	855 (4)
State Wildlife Management Areas			
Finberg	Big Stone	State	5
Allen	Big Stone	State	46
Taffe	Big Stone	State	235
Mallard Hole	Big Stone	State	155
Foley	Big Stone	State	110
Neubauer Refuge	Grant	State	9
Summit Lake	Grant	State	528
Big Stone Ponds	Roberts	State	80
Osterloth	Roberts	State	61
Summit	Roberts	State	320
Little Mud Lake	Roberts	State	90
Smith	Roberts	State	116
Eastman	Roberts	State	265
Roberts County	Roberts	State	40
Peever Slough	Roberts	State	440
Sica Hollow	Roberts	State	360
Turtle Foot	Marshall	State	97
Total			8,121

TABLE 24 (Concluded)

Name of Area	County	Ownership	Acres
Open Space and Agricultural Land			
Watershed Area	Big Stone, Traverse	Private	122,670
Watershed Area	Roberts, Grant, Marshall	Private	551,667
Total			674,337
Public Access Areas			
Ortonville	Big Stone	Ortonville	1
Sester's	Big Stone	Township	1
State Rearing Pond	Big Stone	State	NA
Foster Lodge	Big Stone	Township	1
Bonanza Grove	Big Stone	Township	1
Yankeetown	Big Stone	County	1
Hornstein's Landing	Big Stone	State	3
unknown (17 mi. N. of Milbank)	Roberts	State	1
Milbank Rod and Gun Club	Roberts	State	NA
YMCA Camp	Roberts	Township	NA
unknown (2 mi. N. of Big Stone City)	Roberts	State	1
Big Stone City	Roberts	State	1
Rude Access	Roberts	State	1
Total			12 +
Other			
Municipal Golf Course	Big Stone	Ortonville	148
Sam Brown State Monument	Traverse	State	1
Boy Scout Camp	Roberts	Private	NA
YMCA Camp	Roberts	Private	5
Milbank Rod and Gun Club	Roberts	Private	NA
Hartford Beach Resort	Roberts	Private	NA
Total			154 +

a/ Acreages approximate; includes all parks of the county, not just those within the watershed boundaries.
b/ Acreages approximate.
c/ Numbers in parentheses denote number of areas.
NA Not available.
Source: See Reference Nos. 50, 85-88.

TABLE 25

BIG STONE LAKE WATERSHED
STATE PARKS AND FACILITIES

	Big Stone Lake State Park	Hartford Beach State Park
Land acres	1,092	320
Waterfront (miles)	2 3/4	1 1/4
Roads and Trails (miles)		
General Roads	NA	2
Hiking Trails	7	2 1/2
Major Facilities		
Camping Sites (no.)	42	50
Picnic Area (acres)	2	3
Parking (spaces)	500	120
Play Fields (acres)	8	1
Boat Moorings (no.)	0	1
Beach	2,600 sq. ft.	100 yds.
Interpretive Center (no.)	1	0
Other	Scout Camp	-
Maximum Visitor Capacity	180 Campers 500 Picnickers	NA
Average Annual Visitor Days	15,000	100,000
Origin of Visitors (percent)		
less than 1 hour drive	2	20
1-2 hours drive	5	50
2-3 hours drive	20	20
over 3 hours drive	73	10

Source: Questionaire responses from park managers, June 1974.

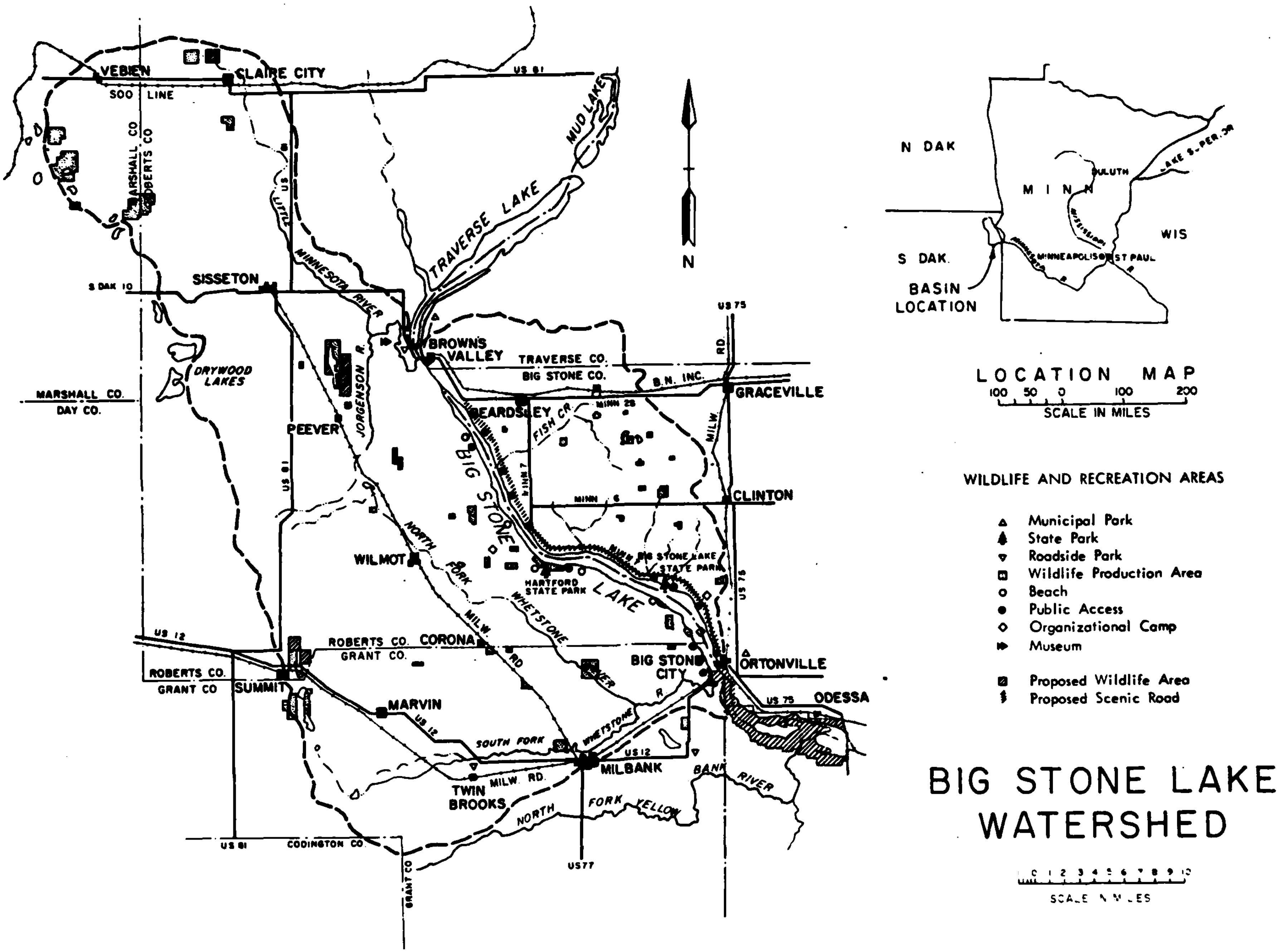

Figure 5 - Big Stone Lake Watershed - Wildlife and Recreation Areas

are 41.4 acres of water per dwelling in Big Stone Lake while the average for the 12 lakes in the county was over 120 acres of water per dwelling.

A partial explanation for the relatively high density development around this lake would appear to be the fishing opportunities. Big Stone Lake had a designation in this study of "bass-panfish-walleye" fish, while the remaining county lakes were all classified as having "winterkill-roughfish" populations only.

As summer and ice fishing, waterfowl hunting, boating, and swimming continue to be among the most popular outdoor recreation activities for this region,[88] water-based recreational resources will become increasingly valuable factors in the area's economy. The future of recreational opportunities in Big Stone Lake Watershed, and to a large part the social well-being of area residents, will greatly depend on three factors: the identification and conservation of land and water areas which would be valuable additions to a system of wildlife, recreation, and scenic areas; the coordination of effort between public and private interests in the development of this system through a program of land and water quality management, recreational development, land purchase, and land use planning and zoning; and the future quality of water and related lakeshore of Big Stone Lake.

In addition to those areas presently designated for conservation use or management, there are several potential or planned expansions which have been identified from various sources, primarily the "Comprehensive Plan for Big Stone County". This plan encouraged the development of a scenic parkway along the length of the Minnesota River from the Twin Cities to Big Stone Lake; this parkway is presently being considered by the Minnesota Conservation and Highway Department. The plan recommended that this route follow the southern bank of the Minnesota River to the lower end of Big Stone Lake, along Minnesota Highway No. 7 northward, and across a new right-of-way along the lakeshore to join with Minnesota Highway No. 26. Also recommended was an expansion of the Ortonville waterfront park to the western edge of the city limits and along both sides of the Minnesota River.

Under a planned project of the Corps of Engineers,[93] the river channel below the control dam will be enlarged for about 2.0 miles and realigned for about 1 mile immediately below the outlet structure. Construction of an earth dam immediately upstream from and paralleling U.S. Highway No. 75 will create a flood-retarding impoundment area which, together with about 1,600 acres of additional bordering lands, will be managed as a national wildlife refuge. Modification of the existing Big Stone Lake outlet control structure will include raising the recently

constructed silt barrier (upstream from the control structure) by 1 ft in order to provide a more desirable water recreation level for Big Stone Lake. While the Minnesota River is just south of the watershed boundary, this project will have a significant effect on recreational opportunities and waterfowl production for the region as a whole. First, while the channel work will provide additional access for canoeing, it may significantly change the scenic value of the river immediately downstream from the outlet control structure. It should be noted that this area is already listed in the canoeing guidebook prepared by the Minnesota Department of Natural Resources;[92] it is part of a 262-mile trip from Ortonville to Shakopee, Minnesota. The following description of the river channel is given:

> "From Ortonville to Marsh Lake, trees and vines intermesh over the river and give the river a jungle-like appearance; dark woods of soft maple, cottonwood, and elms fringe the banks. Obstacles for canoeing the river are broken-down bridges and snags which require chopping through or carrying over."

It may be anticipated that the proposed channel modifications will greatly change this description of the river. Secondly, the addition of a national wildlife refuge will significantly increase opportunities for wildlife management and related uses such as hunting, fishing, bird watching, and photography in the region. Lastly, as low lake levels are a major factor in depressing the recreational value of Big Stone Lake, this project may be expected to increase recreation visitor days to the watershed area.

In an extensive inventory (1971) of the state's potentials in outdoor recreation resources,[94] the Minnesota Department of Natural Resources identified 84 sites (including parks, recreation areas, historic areas, and scientific and natural areas) for which preservation or expansion was needed. Both the north and south units of Big Stone Lake State Park were included among the 84 sites because of the need to expand the state-owned lands in order to control the lakeshore and lake bluffs and overcome the fragmented ownership of the shoreline. It was recommended that the northern unit be expanded by 160 acres and that 184 acres be acquired for the southern unit. The recommendation carried particular emphasis for the northern unit because the scenic and interest value of the landforms there were evaluated at the highest ranking. However, in terms of the state's overall priority rankings, both of these sites were in the lowest 25% of the 84 sites analyzed.

In addition, the present administrator of Big Stone State Park reported[87] that an area about 4 miles south of Beardsley, adjoining the public access there and presently owned by the state, should be designated a research area; and that 160 acres of virgin prairie west of Clinton and northwest of the intersection of County Roads Nos. 6 and 7 should be purchased by the state for permanent protection as a natural area.[87]

The U.S. Fish and Wildlife Service, Buréau of Sport Fisheries and Wildlife identified five additional areas in Roberts County which would be valuable additions to the federal wildlife production areas. Three of them are located near "impassible marsh" (T125N, R50W, Sec 19, 29, and 32); one was northwest of Claire City (T128N, R52W, Sec 11) and one was east of the town of Summit (T122N, R51W, Sec 26). The Minnesota Department of Conservation plans to add approximately 900 acres to the migratory waterfowl areas in Big Stone County.

There are several recommendations for additional developments and land acquisitions contained in the Recreation Plan for Big Stone County[85/] that would be outside of the watershed but have impact on the area. These include enlarging the existing county park and adding three additional sites; creating scenic drives and accesses to open up the area of small lakes northeast of Ortonville; and establishing scenic trails between the proposed lakeshore development at Ortonville and the Corps of Engineers impoundment on the Minnesota River. It should also be noted that potential planned recreation watershed projects in the Minnesota River Subregion of the Upper Mississippi River Basin will add 2,000 acres of surface water to this area by the year 1980 and 4,000 acres by the year 2000.[84/]

Table 26 shows potential expansions or additions of wildlife and recreation lands in Big Stone Lake Watershed. Wildlife management areas in Big Stone County were identified in the state's 1968 recreation survey[89/] and some of them may already have been legally designated.

The primary recreational and wildlife land area in the Big Stone Lake Watershed will continue to be Big Stone Lake. On a historical basis, the lake has been a popular summer resort and recreational area for more than 80 years.[1/] In the 1880's, Ortonville was a tourist center and small steamers carried passengers back and forth to the upper end of the lake. Between 1914 and 1916, an average of 13,000 passengers made an annual tourist trip on these boats. One resident described his experiences living on the shores of Big Stone Lake since 1915:

> "The water in those days was crystal clear. I remember we kids could see fish by the thousands, large and small, from [my father's] dock. I thought of what a wonderful lake Mother Nature had provided us with and of how fortunate we all were to be living on such a beautiful clear body of water while kids living in inland towns over South Dakota were denied such a privilege."[91/]

The last year for any significant commerical tourist travel was 1917, when there was one steamer and seven gasoline-powered boats in the

TABLE 26

POTENTIAL EXPANSIONS OR ADDITIONS OF WILDLIFE AND RECREATION LANDS IN BIG STONE LAKE WATERSHED

Area	Location	Potential Future Management
Big Stone County		
Finberg Wildlife Management Area, 68 acres	T. 123 N., R. 47 W., Sec. 13	State
Allen Wildlife Management Area, 32 acres	T. 124 N., R. 47 W., Sec. 08	State
Taffe Wildlife Management Area, 147 acres	T. 124 N., R. 47 W., Sec. 27	State
Mallard Hole Wildlife Management Area, 50 acres	T. 124 N., R. 48 W., Sec. 25	State
Research Area (part of Big Stone Lake State Park)	4 mi. south of Beardsley	State
Natural Area, Virgin Prairie, 160 acres	T. 123 N., R. 47 W.[a/]	State
Big Stone Lake State Park, Expansions, 235 acres	T. 122 N., R. 47 W.[a/] and T. 123 N., R. 48 W., Sec. 19 and 20	State
National Wildlife Refuge	T. 120, 121 N., R. 45, 46[a/]	
Roberts County		
Waterfowl Habitat	Mud Lake	Federal
Waterfowl Habitat	Bullhead Lake	Federal
Wildlife Production Areas	T. 125 N., R. 50 W., Sec. 18, 19, 20, 29 and 32	Federal
Wildlife Production Areas	T. 128 N., R. 52 W., Sec. 11	Federal
Wildlife Production Areas	T. 122 N., R. 51 W., Sec. 22 and 26	Federal
Recreation Area[b/]	Near Wilmot	State
Recreation Area[b/]	Between Corona and Marvin	State

Sources: Midwest Research Institute, "Outdoor Recreation Planning and Tourism Study for the State of Minnesota," Statistical Summary - County Supply, September 1968.
U.S. Department of Agriculture, Soil Conservation Service, "Preliminary Investigation, North Fork of the Whetstone River Watershed, Roberts and Grant Counties, South Dakota," January 9, 1963.
Questionaire Responses from State Park Managers, June 1974.

a/ Sections unknown.

b/ Small recreation areas in conjunction with construction of potential floodwater retarding structures.

tourist trade. Since then, this use of the lake has largely disappeared. Poor water quality of Big Stone Lake is rapidly reducing its recreational value. The Ortonville Civic and Commerce Association, for example, estimates that property values on the lakeshores would be 25-50% higher if there were no noticeable pollution in the lake (particularly green color and odor).[84/] The south end of the lake is so filled with sediments that its recreational value is greatly restricted and the City of Ortonville has elected to build a municipal swimming pool because the lake has become unfit for body contact water sports. Administrators of Big Stone Lake and Hartford Beach Parks ranked water quality of Big Stone Lake in relation to recreational use of the parks as "a very great problem" and "a significant problem", respectively. Poor water quality of the lake is the single greatest deterrent to expanded use and greater recreational development.

D. Physiographic Elements

1. Geologic

a. Location and drainage: Big Stone Lake is an interstate body of water bordering Minnesota and South Dakota and is located at the head of the Minnesota River (Figure 1). Its watershed includes portions of Roberts, Grant, and Marshall Counties, South Dakota, and Big Stone and Traverse Counties, Minnesota. The watershed, which is located about 100 air miles south of Fargo, North Dakota, had a population of 19,122 in 1970.[95/] Although about two-thirds of the total population lives in municipalities, agriculture is the primary resource of the area.

The principal tributaries to Big Stone Lake include the Whetstone River and Little Minnesota River. The Whetstone River, which drains an area of 395 sq miles, enters the lake from the southwest near the lake's outlet. The Little Minnesota River, with a drainage area of 463 sq miles, rises in the South Dakota hills northwest of the lake and empties into the upper end of the lake. In addition, 59 and 213 sq miles of South Dakota and Minnesota lands, respectively, drain into the lake by way of small streams and overland flow. The 19-sq mile lake also receives water from rain and snowfall and from numerous springs under the water surface. The drainage areas at existing gaging stations and other key locations within the watershed are given in Table 27.

TABLE 27

DRAINAGE AREA, BIG STONE LAKE WATERSHED

Station	Drainage Areas (sq miles) Above Station South Dakota	Minnesota	Other	Total
Little Minnesota River				
Peever, South Dakota	447	-	-	447
Mouth	463	-	-	463
Whetstone River				
Big Stone City, South Dakota	389	-	-	389
Mouth	395	-	-	395
Small streams and overland drainage	59	213	-	272
Big Stone Lake	-	-	19	19
Outlet of Big Stone Lake	917	213	19	1,149

b. Physiography: The Big Stone Lake Watershed lies within the Western Lake Section of the Central Lowland physiographic province.[96] The watershed is the headwater source of the Minnesota River, a tributary of the Mississippi River, and is located at the diversion of three major drainage systems. The western boundary of the area is the "Coteau des Prairies", or "Hills of the Prairies", an escarpment that marks the divide between the Minnesota and Missouri River drainage basins. Brown's Valley, between Lake Traverse and Big Stone Lake, is located on the Continental Divide between the Minnesota-Mississippi Rivers and Red River of the North-Hudson Bay drainage basins.

c. Topography: The watershed is an upland plain or prairie above the lake level. The surface of the eastern two-thirds is nearly level to gently undulating while the western one-third consists of steep rolling hills. Patches of nearly level terraces are found below the bluffs which border the lake.

The highest elevation of about 2,000 ft above sea level occurs in the Sisseton Hills which are a subdivision of the "Coteau des Prairies" in the western portion of the watershed. Within a short distance to the east, near Veblen, Claire City, and Wilmot, South Dakota, the

elevation decreases abruptly to between 1,150 and 1,200 ft. This general area consists of poorly drained lands with abundant lakes and potholes which retain much of the sediment eroded from the Sisseton Hills. The topography of this plain is typical of that formed by glaciers. Gently rolling hills are interspersed throughout with small areas of more rugged topography which were formed during minor halts of retreating ice sheets. In the South Dakota section of the watershed this plain ends at the bluffs next to Big Stone Lake. However, about 6-10 miles west of Big Stone Lake, tributaries have cut valleys into the bluffs and the land elevation decreases as much as 200 ft to the 967 ft lake elevation. Because of the rapid runoff of surface waters from these tributaries much of the sediment carried into Big Stone Lake is eroded in these valleys.

The Minnesota portion of the watershed is bounded on the east by a glacially formed ridge which ranges in elevation from 1,150-1,190 ft. Most of the area ranges from 1,100-1,125 ft in elevation and is a continuation of the plain on the South Dakota side of Big Stone Lake. A few miles east of the lake, tributaries to the lake have their headwaters and have cut valleys through the bluffs similar to those on the western side of the lake. On this side the height of the bluffs ranges from 125-150 ft.

The Minnesota River Valley which includes Big Stone Lake is incised 125-200 ft below the adjacent uplands. Deep gulleys ranging from 1/2-2 miles in length have been eroded into the bluffs bordering the lake.

d. Climate: The climate of Big Stone Lake Watershed is of the humid continental, cool summer type.[97/] The average length of the growing season is 136 days.[1/] The average date of the last killing frost in the Spring is May 12 and the average date of the first killing frost in the Fall is September 26. Average temperatures range from 12°F in January to 74°F in July, with a yearly average of 44°F.[95/] Extreme temperatures have ranged from a low of -41°F to 114°F.

Annual precipitation averages about 22 in. and has varied from a low of 10.8 in. at Sisseton, South Dakota, in 1871 to a high of 35.3 in. at Milbank, South Dakota, in 1906. The annual snowfall totals about 36 in. and comprises about 16% of the average annual precipitation. About 70% of the annual precipitation occurs during the period May through September. The maximum 24-hr daily amount of 5.50 in. was recorded at Sisseton on May 27, 1954. Greater amounts of precipitation may be experienced for shorter durations. Thunderstorms with hail are common during the growing season. Because of the northwest-southeast orientation of the lake, the prevailing winds from the northwest have a tendency to "pile up" water at the southern end of the lake causing short-term fluctuations in water levels.

The lake loses an average of about 13.5 in. more water from evaporation annually than it receives from precipitation falling directly on the lake surface. This deficiency is made up by water draining from adjacent lands and from ground water inflow. It is estimated that more than 60% of the average annual evaporation from the lake itself occurs from June through September. This estimate of water loss does not include losses from transpiration of plants or from seepage.

More detailed weather information is available from the National Weather Service for the Big Stone Lake Watershed. Weather observations are currently being obtained from six stations within the watershed. These stations and the length of record available from each are listed in Table 28.

TABLE 28

WEATHER STATIONS IN BIG STONE LAKE WATERSHED

Station	Length of Record, in Years	
	Precipitation	Temperature
Ortonville, Minnesota	32	-
Beardsley, Minnesota	76	74
Milbank, South Dakota	83	83
Summit, South Dakota	16	16
Wilmot, South Dakota	28	-
Sisseton, South Dakota	66	50

e. Soils: The watershed is underlain by soils of the Barnes-Buse-Aastad Association.[95] In the uplands the soils have developed from glacial deposits and are primarily composed of moderately permeable mixtures of sand, silt, and clay. The soils in the bottom lands and shallow depressions are generally heavy clays. They are composed largely of reworked alluvial material derived from the uplands.

Four general soil types have been mapped on the flood plain of the Whetstone River. They are Maple, Lamoure, moderately well-drained Lamoure, and Fargo-like silty clay loam.[98] The Maple soils have high salt content and it has been determined that on 50% of the flood plain, crop production is affected by the salt.

f. Geology

(1) Geologic history of Big Stone Lake: The original Minnesota River Valley was eroded and established during the Tertiary Period.[95] During the ensuing Pleistocene Epoch, glacial ice sheets which advanced from the north scoured and deepened the valley. About 8,000 years ago, as the last ice sheet melted, a ridge of ice and rock materials (moraine) was deposited near the upper end of the present Big Stone Lake. The river valley became blocked with rock and soil debris, and as the glacier receded farther to the north, water from the melting ice became ponded north of the moraine.

As a result, glacial Lake Agassiz, which covered most of eastern North Dakota and northwestern Minnesota and a small part of northeastern South Dakota, was formed.[1] The water in Lake Agassiz eventually eroded an outlet channel through the barrier and the ponded meltwater in the lake began to drain southward. As the drainage waters increased, a large glacial, River Warren, formed a wide deep valley from the foot of the present Lake Traverse through much of south central Minnesota. The valley of River Warren is the present Minnesota River Valley. When the water levels of Lake Agassiz were highest, this channel could not carry all the water and part of it was rerouted westward where a second channel formed. This channel, which is about 1/2 mile wide, 20 miles long, and 80 ft deep, is now known as Cottonwood Slough.[99] Eventually, the direction of flow from Lake Agassiz reversed and the lake began draining northward along the present Red River of the North.

For many years following the glacial drainage, Whetstone River carried large quantities of sediment from its headwaters in South Dakota and deposited them in the Minnesota River Valley near Ortonville, Minnesota. The sediments formed a delta and a natural dam which retarded runoff from land above the delta. As a result, Big Stone Lake was formed in the valley above the mouth of the Whetstone River. To the north, a similar delta, deposited by the Little Minnesota River near Brown's Valley, separates Big Stone Lake and Lake Traverse.

(2) Stratigraphy: Precambrian metamorphic and igneous rocks underlie the entire area, but are exposed only below Big Stone Lake in the Minnesota River Valley and in the vicinity of Milbank, South Dakota (see Table 29). The rock types include mica schist, granite gneiss, and granite. The granite which is exposed has been quarried extensively and is known as the Milbank granite. It is a dark to medium red stone which takes a high polish.[100] Although the regional extent of the granite is not known in detail, its depth of over 200 ft and uniform composition indicate that it may have originated as an intrusive mass. Where the Precambrian rocks are overlain by Cretaceous strata, their upper 20-150 ft

TABLE 29

GENERALIZED COLUMNAR SECTION AND WATER-BEARING CHARACTERISTICS

Geologic Age	Material	Thickness (ft)	Areal Extent	Water-Yielding Potential
Pleistocene	Near-surface sand and gravel	0-100 Average about 30	Spotty throughout the watershed.	Good. Wells finished in this material yield several hundred gpm (gal/min). One well yields 1,200 gpm. Numerous springs occur.
	Till	0-300 Average about 200	Present over entire watershed except where granite is exposed	Poor. Not known to yield water to wells in the watershed.
	Buried sand and gravel	0-40 Average about 5	Occurs as lenses or pods within or at the base of the till.	Fair. Wells finished in this material yield up to 250 gpm.
Cretaceous	Shale	0-400 Average about 150	Underlies much of the area. Exposed at the surface near the north end of Big Stone Lake.	Poor. A few wells reportedly obtain 5-10 gpm from fractures in the shale.
	Sandstone or sand	0-40 Average about 5	Occurs as beds within, and at the base of the shale.	Fair. Yields up to 150 gpm to wells.
Precambrian	Granite	?	Underlies entire area. Exposed at the surface near Ortonville and Milbank.	Poor. Not known to yield water to wells in the area.

Source: Table modified from U.S. Geol. Survey Hydrologic Investigations Atlas HA-213 (1966).

have been altered by weathering to dry, white to green, gritty or silty kaolinitic clay.[101] The clay becomes denser with increasing depth and grades into unaltered crystalline rocks. The general slope of the Precambrian surface is westward. At Brown's Valley, mica schist has been encountered at an elevation of 540 ft, while at Ortonville, granite is exposed at an elevation of 975 ft.[95]

Sedimentary rocks of Cretaceous age directly overlie the Precambrian surface throughout most of the area (see Table 29). During early Paleozoic time the area was submerged and marine strata were deposited. However, subsequent uplift of the area caused erosion of these rocks. The area was not submerged again until Cretaceous time. The Cretaceous rocks consist of soft bluish-gray clayey shale interbedded with sandstone. The sandstone often occurs at the base of the shale and is generally only a few inches to a few feet thick. This sandstone has been correlated with the Dakota formation.[101] The Cretaceous rocks thicken toward the west and are known to reach a thickness of 440 ft at Brown's Valley. Cretaceous age shale crops out in the Little Minnesota River Valley at the north end of Big Stone Lake.

Glacial drift of Pleistocene age covers the bedrock surface throughout most of the area and commonly ranges between 100-300 ft thick (see Table 29). It is generally a heterogeneous mixture of dark gray dense clay, sand, gravel, and boulders which are called till. Thin sand and gravel layers occur erratically within and between the till layers. Sediments which form the drift were eroded by the glacial ice from the Cretaceous and Precambrian bedrock to the north and transported to this area.[95] A variety of topographic features formed by the glaciers such as moraines (ridges), kettles (depressions), and outwash plains occur in the watershed.

Bordering Big Stone Lake below the bluffs are Pleistocene terrace remnants of glacial outwash sand and gravel.

Recent alluvium composed of dense clay, silt, sand, and gravel occurs in the stream valleys. Organic silt, clay, and small deposits of peat occur in the lower marshy areas of the flood plains and isolated upland areas.

g. Mineral resources: Mineral deposits of economic value currently exploited in the watershed consist of glacial sand and gravel, which are used primarily in local building and road construction. Total production and value of sand and gravel for each county are shown in Table 30, because the production cannot be separated according to the boundaries of the watershed.[95] Stone quarries which are active in Grant County, South Dakota, and Big Stone County, Minnesota, are excluded because they lie

outside the boundaries of the study area. However, high quality granite from these quarries has been distributed nationally for a variety of uses.

TABLE 30

SAND AND GRAVEL PRODUCTION IN THE BIG STONE LAKE WATERSHED

County	Year	Production (tons)	Value
Big Stone County, Minnesota	1969	222,000	$157,000
	1970	143,000	115,000
Grant County, South Dakota	1969	224,000	225,000
	1970	(no figures available)	
Roberts County, South Dakota	1969	95,000	88,000
	1970	75,000	95,000
Marshall County, South Dakota	1969	152,000	166,000
	1970	162,000	189,000

Source: U.S. Bureau of Mines data.[95]

h. Hydrology

(1) Stream and surface water characteristics: The origin, amount, and effect of surface water drainage on Big Stone Lake is important because most of the nutrients which cause the present water quality problems in the lake have been and are being carried by these waters.

Big Stone Lake has two major tributaries, both of which drain the South Dakota portion of the watershed. The Little Minnesota River originates as an intermittent stream in the Sisseton Hills. It flows steeply from an elevation of about 1,750-1,250 ft in a 3-mile distance, an average drop of 170 ft/mile. The gradient of the river then decreases to about 32 ft/mile as it drops to an elevation of about 1,070 ft in 21 miles at its confluence with the Jorgenson River, its only major tributary. From that point, the river falls to the elevation of Big Stone Lake, 967 ft, in about 15 miles, an average drop of 6.9 ft/mile.[95]

The second major tributary of Big Stone Lake is the Whetstone River. Its North and South Forks, which flow intermittently, form a fan-shaped stream system that drains the southwestern part of the watershed. Both streams have their source in the Sisseton Hills near the western border of the watershed and are of nearly equal length. From their headwaters to where they join to form the main stem of the Whetstone River, the North and South Forks fall from elevations of 1,850 and 1,950 ft, respectively, to an elevation of 1,030 ft in 30 miles. Below the confluence of the North and South Forks, the main stem drops about 85 ft in 10 miles to its entry into the southern tip of Big Stone Lake, a gradient of 8.5 ft/mile.

The Minnesota section of the watershed is drained by Fish Creek and small creeks which enter directly into Big Stone Lake from the east. Other small creeks flow directly into the lake from the South Dakota side. About 84% of the total surface water drainage comes from South Dakota and about 16% from Minnesota.

Streamflows in the watershed generally attain peaks in March or April following snowmelt and diminish thereafter except for short periods of increased runoff following heavy rains. Minimum flows occur in late fall and winter and frequently reach zero or near zero flows.

Floods on the Minnesota River at and below Ortonville are modified by temporary storage in Big Stone Lake which has a surface area of about 19 sq miles. Prior to 1937 when the existing works on the Minnesota and Whetstone Rivers as constructed by the Works Progress Administration were place in operation, a substantial part of the Whetstone River flow passed directly down the Minnesota River Valley. The works as completed in 1937 provided for a diversion of the Whetstone River to bring its flow into the Minnesota River a short distance upstream from an outlet control dam constructed on the Minnesota River. The crest on the control dam was set to maintain the lake level at an elevation of 963.7 ft. Stop logs were provided to divert water upstream to raise the levels of Big Stone Lake during drought and low lake level periods. During the period from 1937 to July 1947, levels on Big Stone Lake were regulated by operation of stop logs in the structure at the lake outlet and much of the Whetstone River flood flows were diverted into the lake. However, after July 1947, the stop logs were not used and the diversion of Whetstone River flows into the lake was dependent upon the capacity of the unregulated dam and downstream channel. However, since 1958 the lake levels have been partially regulated by operation of gates at the control structure and by a silt barrier constructed upstream from the outlet structure to prevent excessive siltation of Big Stone Lake from Whetstone River flows.[102]

(2) Streamflow records: Streamflow data are being obtained by the U.S. Geological Survey at three gaging stations within the watershed. These stations are located on the Little Minnesota River near Peever, South Dakota; the Whetstone River near Big Stone City; and the Minnesota River at the outlet of Big Stone Lake. Pertinent streamflow data for the three gaging stations as well as other significant locations are summarized in Table 31.

Minimum flows of the gaged streams are not included in Table 31. However, records indicate that there are occasional periods of zero flow in the Whetstone River during most years and there has been zero flow in the Little Minnesota at times during 1940, 1942, 1950, 1954, 1957, 1959, and 1963.[1/] On December 13, 1940, there was no flow in the Minnesota River at Ortonville. The land areas in South Dakota and Minnesota which drain directly into the lake have generally had periods of zero flow during dry years. Although a few small, spring-fed streams in the ungaged areas may have contained small amounts of water during these dry years, it is doubtful that this water reached the lake.

In addition to streamflow data, lake levels of Big Stone Lake have been recorded at Ortonville from 1937 to 1966.[103/] During this period the maximum stages recorded were 12.40 ft in 1942 when lake levels were regulated at the outlet dam and 12.73 ft in 1952 when lake levels were unregulated. The minumum stage during the period of record was 2.20 ft in 1940. The gage height (fixed crest of outlet dam) is 5.95 ft.

Many days each year from 1937 to 1947, when lake levels were regulated, with the exception of 1942, the lake surface was below the present outlet dam crest. Since 1958, during the period of partial regulation about one-half the years had lengthy periods of lake levels below the outlet dam crest.

(3) Analysis of streamflow records: Discharge records for the U.S. Geological Survey stream-gaging station on the Minnesota River at Ortonville represent combined outflows from Big Stone Lake under various plans of operation (by the State of Minnesota), and runoff from Whetstone River. The average annual outflow is about 82,000 acre-ft (Table 31). Although no measured evaporation data are available, it is estimated that the average annual evaporation loss from the lake is about 32 in.[104/] Since the average annual precipitation is about 22 in., the lake loses about 10 in. (10,300 acre-ft) more water from evaporation annually than it receives in direct precipitation falling on the lake surface. However, the lake currently receives an average annual surface water inflow of about 80,000 acre-ft from its tributaries (see Table 31). This inflow is assumed to include nearly all of the flow of the Whetstone River.

TABLE 31

SUMMARY OF SURFACE WATER FLOW WITHIN THE BIG STONE LAKE DRAINAGE BASIN

Location	Drainage Area, Square Miles	Maximum Discharge Observed cfs	Maximum Discharge Observed Date	Average Flow cfs	Average Flow Acre/feet/year	Period of Record	Remarks
Little Minnesota River near Peever, South Dakota	447	4,730	4-8-52	50.1	36,272	1939 to present	Gaging station. Flows to this point are directly measured.
Little Minnesota River from gaging station to mouth	16	-	-	1.4	1,014	1932 to present	Flow estimated.
Whetstone River above Big Stone City, South Dakota	389	6,870	4-8-69	46.6	33,738	1910 to 1912, 1931 to present	Gaging station. Flows to this point are directly measured.
Whetstone River from gaging station to mouth	6	-	-	0.7	507	1932 to present	Flow estimated.
Land in South Dakota between Little Minnesota and Whetstone Rivers directly tributary to Big Stone Lake	59	-	-	2.4	1,738	1932 to present	Flow estimated. Flow from a few streams and from overland runoff.
Land in Minnesota directly tributary to Big Stone Lake	213	-	-	9.0	6,516	1932 to present	Flow estimated. Flow from small streams, mostly spring fed and from overland runoff.
Minnesota River at Ortonville	1,149	3,060	4-13-52	113.0	81,870	1938 to present	Gaging station. Flows at this point are directly measured and include the drainage from all of the above listed areas and Big Stone Lake.

Table modified from Big Stone Lake study, 1967, Big Stone Lake, Minnesota and South Dakota Plan of Study for Pollution Control and Abatement, 1973, and U.S. Geol. Survey Hydrologic Atlas HA-213, 1966.

In addition, the estimated annual ground water inflow is 15,000 acre-ft.[95] Therefore, the surface water and ground water inflows to the lake (95,000 acre-ft) are slightly greater than the evaporation loss deficiency and surface water outflow (92,300 acre-ft) under average annual conditions. The surplus inflow may be lost to seepage and transpiration losses. The interpretation of the above values is accomplished with the realization that errors may exist in the determination of the volume of inflow.

During drought conditions when stream flow might be zero, evaporation combined with other losses could exceed inflows to the lake with a resultant drop in lake levels. The stability of the lake under drought conditions is aided greatly by inflow from the Whetstone River which accounts for about 38% of the total surface water inflow of the lake. With the proposed future modification of the existing outlet control structure and silt barrier,[102] only 15% of the Whetstone River will flow into Big Stone Lake.[105] This flow represents approximately 10% of the total surface water inflow of the lake.

No attempt has been made in recent years to store floodwaters in the lake when its water stage is 6 in. or more above the spillway of the outlet dam. Between June 30 and November 1 of most years, an attempt is made by operation of the control gates to maintain a water stage between the spillway crest elevation and 6 in. above it in order to minimize outflow from the lake due to wave action and "pile up". This is accomplished by placing or removing timber crest gates, the tops of which are 1.25 ft above the concrete spillway.

At the elevation of the crest of the outlet dam, Big Stone Lake has a surface area of about 12,360 acres and an average depth of 11 ft. The lake has, at this level, a normal storage capacity of about 136,000 acre-ft of water. As previously discussed, the lake receives an average annual surface water inflow of about 80,000 acre-ft of water. However, there is a great deal of surface water stored in the lake during periods of high stream flow. For example, during the period April 1-20, 1952, the lake received an estimated inflow of 167,746 acre-ft and the recorded outflow from the lake for this period was 81,693 acre-ft, indicating storage of 86,053 acre-ft of water during this 20-day period.[1] About 44% of the surface water inflow to the lake at this time was derived from the flow of the Whetstone River, showing that the Whetstone River has at times a greater effect on the lake than the size of its drainage area might indicate. Big Stone Lake has always temporarily stored a large amount of water at times of high runoff, even under natural conditions when the drainage area was 735 sq miles and did not include the Whetstone River Watershed.

From the previous discussion, Big Stone Lake has a storage volume of about 136,000 acre-ft, as compared to about 82,000 acre-ft that, in an average year, can be expected to flow from the lake. Thus, assuming even mixing of the water in the lake, the water in the lake can be expected to be replaced by "new" water from the watershed and underground sources in less than 2 years. This is a more rapid rate of exchange of water than is found in most lakes.[73] In its original state without inflow from the Whetstone River, the lake water was replaced about every 3 years.

Much of the runoff which the lake receives from the watershed (a third to a half in many years) takes place in late winter and spring (especially from late February through May). Early in this period, subsoil may be frozen and soil particles, material on the surface such as agriculture fertilizers, manure, and soluble nutrient salts such as nitrates in the surface soil, can easily be carried into the lake with runoff water. In contrast, the flow of ground water, which makes up about one-sixth of the water entering the lake, is generally more constant throughout the year as is its chemical quality.

The maximum flow of record for the Minnesota River at Ortonville occurred in the Spring of 1952 and followed a winter of heavy snowfall. Big Stone Lake reached a maximum elevation of 970.42 ft and outflow from the lake reached a peak discharge of 3,060 cfs (cubic feet per second) on 13 April. This represents a discharge of approximately 2.6 cfs per sq mile of contributing drainage area. It is estimated that the 1952 flood has a recurrence frequency of about once in 60 years. The next largest flood occurred in the Spring of 1947 when a maximum outflow from the lake of 1,660 ft/sec was recorded.[73]

(4) Water quality: Both surface water and ground water are valuable assets, as both supplies are essential to man's existence. The National Technical Advisory Committee[2] developed criteria for five general areas of water use: (1) Recreation and Aesthetics; (2) Public Water Supplies; (3) Fish, Other Aquatic Life, and Wildlife; (4) Agriculture, and (5) Industry.

Standards were recommended and various criteria (scientific requirement on which judgment may be based concerning the suitability of water quality to support a designated use) established for adoption by all states.

Various parameters are required to quantify water quality and those routine measurements are a valuable tool in assessing pollution point sources as the general suitability of waters to comply with a designated use. Routine monitoring can supply data essential for surveillance of various waters and for maintaining and/or improving water quality.

2. Surface water

a. Pollution sources for the Big Stone Lake and its tributaries: Big Stone Lake is a eutrophic body of water which basically contains nutrients (principally phosphorus and nitrogen) in concentration levels conducive to nuisance growths of aquatic plants including phytoplankton (algae). Both of these major nutrients are essential for aquatic flora as they are for terrestrial flora. The various sources from which waters may receive these nutrients are enumerated below.

Nitrogen sources are: atmospheric (approximately 5 lb/acre/year); domestic sewage effluents; animal and plant processing wastes; animal manure; fertilizer and chemical manufacturing spillage; various types of industrial effluents; and agricultural runoff.2/

Phosphorus sources are: domestic sewage (which includes detergents that contain phosphate builders to enhance soil removal); animal and plant processing wastes; fertilizer and chemical manufacturing spillage; various industrial effluents; and, to a limited extent, erosion materials in agricultural runoff.2/

Sources of pollution for Big Stone Lake are of two general types: point sources, which can be identified as occurring at a specific point location and are subject to control measures; and areal or nonpoint sources which occur from land runoff, dissolved nutrients in underground waters, nitrogen fixation by bacteria and certain algae, etc., and are difficult to control.1/

(1) Point source pollution: Nutrients from the Big Stone Lake Watershed which have a potential effect on the lake are shown in Table 32 and include: municipal, resort oriented, and residential wastes; industrial wastes; and feed lot animal wastes.

Because concentrations of phosphorus are considered a determining factor in aquatic plant growth, including algal nuisance growth,2/ estimates of this major plant nutrient are given in Table 32 for each source listed.

Of the 14 incorporated municipalities in the watershed, seven have sewage collection and treatment works. Data obtained on sewage effluents from one of the municipalities, Brown's Valley, Minnesota, is shown in Table 33. The total phosphorus contribution is 3,011 lb/year which is near the value reported in Table 32 from another source. The other municipalities, resort oriented sources, and residential sources utilize either privy or septic tank facilities. This includes approximately 314 homes and cottages in 26 resort areas, five homes not connected with resorts, and six licensed facilities providing food and public lodging.1/

TABLE 32

POTENTIAL POINT AND AREAL SOURCES OF NUTRIENT ENRICHMENT TO BIG STONE LAKE

POINT SOURCE POLLUTION

Name and Location of Source (population)	Origin and Control on Treatment Provided (date constructed) Sewage	Effluent is Discharged to	Estimated Annual Phosphorus Contribution (pounds/year)
	Municipal, Resort Oriented, and Residential		
Barry, Minnesota (60)	Primary sewage treatment plant (1938)	Slough	None
Beardsley, Minnesota (410)	Privies and septic tanks	Soil	None
Big Stone City, South Dakota (718)	Sewage stabilization ponds (1963)	Evaporation and soil	None
Brown's Valley, Minnesota (1,033)	Secondary sewage treatment plant (1956)	Little Minnesota River to Big Stone Lake	2,700
Claire City, South Dakota (86)	Privies and septic tanks	Soil	None
Corona, South Dakota (150)	Privies and septic tanks	Soil	None
Marvin, South Dakota (93)	Privies and septic tanks	Soil	None
Milbank, South Dakota (3,500)	Secondary sewage treatment plant and polishing ponds (1964)	South Fork of Whetstone River to Big Stone Lake	2,800
Peever, South Dakota (208)	Privies and septic tanks	Soil	None
Sisseton, South Dakota (3,218)	Sewage stabilization ponds (1955)	Creek to Little Minnesota River to Big Stone Lake	4,000
Twin Brooks, South Dakota (86)	Privies and septic tanks	Soil	None
Veblen, South Dakota (437)	Sewage stabilization ponds (1954)	Dry run	None
Wilmot, South Dakota (545)	Sewage stabilization pond (1958)	Slough	None
Blue Cloud Abbey, Marvin, South Dakota	Sewage stabilization pond (1961)	Creek to South Fork Whetstone	50
Big Stone Lake State Park, Minnesota	Privies and septic tanks	Soil	None
Hartford State Park, South Dakota	Privies	Soil	None
Lakeshore residences, cabins, resorts, camps, etc.	Privies and septic tanks	Soil or Big Stone Lake	150

TABLE 32 (Concluded)

Name and Location of Source (population)	Origin and Control on Treatment Provided (date constructed) Sewage	Effluent is Discharged to	Estimated Annual Phosphorus Contribution (pounds/year)
	Industrial Wastes		
Beardsley Locker Company Beardsley, Minnesota	Slaughtering wastes septic tanks	Soil	None
Otter Tail Power Company Ortonville, Minnesota	Cooling water, boiler blow-down	Big Stone Lake	50
Frigo Cheese Company Big Stone City, South Dakota	Process wastes, seepage ponds	Soil	None
	Feed Lots		
Eight feeder lots in Minnesota immediately adjacent to lake or tributaries	Livestock feeding - little or no control	Water courses, ditches and direct flow	21,000
(214 Feedlots - Table 3)	214 Feedlots needing or possibly needing control	See Table 3	663,000 b/
	Other Sources		
Land runoff	Snow melt and storm water carrying fertilizer residues and soil	Water courses ditches and direct flow	57,000
Ground water seepage	Natural flow and quality--no control	Big Stone Lake	2,000 a/

Summary

		TOTAL 90,000 a/
		-21,000
Sewage	9,700	69,000
Industrial Wastes	50	+663,000 b/
Feed Lots	21,000 or 663,000	732,000 a,b/
Other Sources	59,000	
Total	90,000 a/ or 732,000	

a/ Figures rounded.
b/ Feedlot Survey, South Dakota Department of Health and USDA, Soil Conservation Service, Big Stone County, Minnesota (1973).
Source: Big Stone Lake Study, A Joint Report by Minnesota and South Dakota, November 1967.

TABLE 33

WATER QUALITY OF SEWAGE PLANT EFFLUENT
AT BROWNS VALLEY, MINNESOTA
(Lat. 45° 35' 20" Long. 96° 50' 00")

Date	Time of Day	Nitrates and Nitrites as N (mg/ℓ)	Kjeldahl Nitrogen as N (mg/ℓ)	Ammonia as N (mg/ℓ)	Orthophosphate as P (mg/ℓ)	Total Phosphate as P (mg/ℓ)	Flowrate (MGD)	Total Phosphorus as P (lb/yr)	Total Nitrogen as N
1/31/73	1100-1300	1.200	38.000	7.600	4.200	8.400	0.150	3837.5	17,885
2/26/73	1100-1300	1.370	25.000	5.700	3.200	--	--	--	
3/27/73	0900-1100	1.900	7.300	0.190	0.870	1.650	0.100	503.2	2,802
4/24/73	1100-1300	0.900	25.200	6.500	3.500	6.500	0.100	1982.3	7,744
5/29/73	1000-1300	1.580	12.000	0.450	2.200	6.800	0.200	4147.0	8,272
6/19/73	1100-1300	2.500	11.600	0.198	3.000	6.200	0.200	3781.6	8,588
7/27/73	1100-1300	2.310	30.000	9.000	3.780	8.100	0.200	4940.0	19,660
12/12/73	0800-1530	5.000	16.000	4.500	4.800	8.100	0.125	3087.0	7,795
1/14/74	0800-1400	0.800	--	5.400	4.000	--	0.188	--	--
							Average	3011.0	10,392

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon, June 4, 1974.

Of the three industrial waste sources listed, only the Otter Tail Power Company contributes to the phosphorus enrichment problem (see Table 32).

Feedlot contributions (Table 32) were calculated originally on only eight feedlots in the Minnesota portion of the watershed[106] and accounted for only a fraction of the potential pollution nutrients entering the Big Stone Lake. Feedlot inventories by both the states of Minnesota and South Dakota[107-109] provided calculations for more realistic contributions of pollution nutrients to the watershed from animal sources (Table 34).

Based upon the more recent data,[107-109] feedlots in the watershed provide approximately 90% of the total potential phosphate contribution to the Big Stone Lake.

(2) Areal sources: Areal sources of pollution are shown as other sources and include land runoff and ground water seepage which are included in Table 32. These sources are estimated to comprise about 7.7% of the total phosphate contribution to Big Stone Lake.

b. Water quality criteria and standards: Specific assigned use categories for bodies of water play a significant role in the parameters and standards essential to enhance or maintain water quality.

Surface waters for the Big Stone Lake Watershed are covered by standards of both the states of Minnesota and South Dakota. The Little Minnesota River from the South Dakota border to its entry into Big Stone Lake, the Big Stone Lake proper, and the Whetstone River are classified as interstate waters.

Water quality criteria and standards for both South Dakota and Minnesota are shown in Appendices G and H, respectively, and include standards for applicable intrastate waters. A condensation of applicable water quality criteria covered by both states is shown in Table 35, with the addition of intrastate waters, the North and South Fork of the Whetstone River.

The most significant differences in standards set by the two states for the same waters are: maximum fecal coliform counts for the Little Minnesota River (200/100 ml for Minnesota and 1,000/100 ml for South Dakota), maximum oil concentrations allowed in Big Stone Lake (0.5 mg/liter for Minnesota and 10.0 mg/liter for South Dakota, and maximum turbidity values for the interstate waters (25.0 JTU for Minnesota and 50.0 JTU for South Dakota).

TABLE 34

STATUS OF FARM FEEDLOTS IN THE BIG STONE LAKE WATERSHED

Status	No. of Feedlots in South Dakota Portion of Watershed*	No. of Feedlots in Minnesota Portion of Watershed**	Combined Total
a. Needing or Possibly Needing Treatment	191	23	214
b. Not Needing Treatment	177	52	229
c. Treated	2	12	14
Total	370	87	457
Maximum Phosphorus (P)*** Contribution from feedlots shown under (a.)	584,000 lbs/yr	79,000 lbs/yr	663,000 lbs/yr

Source:
* Date for South Dakota were furnished by the South Dakota Department of Health as a result of a conducted field investigation in 1973. This inventory represents those feedlots which drain into major watercourses only and questionaires returned by farmers and do not represent the total number of feedlots in the South Dakota portion of the Big Stone Lake Watershed.
** Data for the Minnesota portion of the watershed were compiled by the Soil Conservation Service for Big Stone County only. This inventory assumes that feedlots on or within 1000 ft of a major watercourse require or possibly need treatment.
*** Assuming each animal unit (1 steer, beef cow, feeder) provides .088 pounds of phosphorus/day.

TABLE 35

COMPARATIVE WATER QUALITY STANDARDS FOR INTERSTATE WATERS IN THE BIG STONE LAKE WATERSHED COMMON TO MINNESOTA AND SOUTH DAKOTA AND TWO WHETSTONE RIVER TRIBUTARIES

	Big Stone Lake		Whetstone River and North Fork		Whetstone River South Fork	Little Minnesota River	
Characteristic	Minnesota	South Dakota	Minnesota	South Dakota	South Dakota	Minnesota	South Dakota
Dissolved Oxygen (min)	6.0(April-May) 5.0	6.0(April-May) 5.0	5.0(April-May) 4.0	-- 5.0	-- 5.0	5.0(April-May) 4.0	-- 5.0
Temperature	86°F	80°F	90°F	90°F	90°F	90°F	90°F
Ammonia(N)	1.0	1.0	1.5	1.0	1.5	1.5	1.0
Chromium(Cr)	0.05	--	0.05	--	--	0.05	--
Copper(Cu)	0.01	--	0.01	--	--	0.01	--
Cyanides(CN)	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Free Cyanides	--	0.005	--	0.005	0.005	--	0.005
Oil	0.5	10.0	10.0	10.0	10.0	10.0	10.0
pH Value	6.5-9.0	6.5-9.0	6.5-9.0	6.3-9.0	6.0-9.0	6.5-9.0	6.3-9.0
Phenols	0.01	--	0.1	--	--	0.1	--
Turbidity (JTU)	25.0	50.0	25.0	50.0	50.0	25.0	50.0
Fecal Coliform Organisms	200MPN / 100 Ml	200 MPN / 100 Ml	200 MPN / 100 Ml	1000 MPN / 100 Ml	1000 MPN / 100 Ml	200 MPN / 100 Ml	1000 MPN / 100 Ml
Undisassociated H_2S	--	0.002	--	0.002	0.002	--	0.002
Total Iron	--	0.2	--	0.2	0 2	--	0.2
Suspended Solids	--	90.0	--	90.0	90.0	--	90.0
Coliform Organisms	--	1000 MPN / 100 Ml	--	5000 MPN / 100 Ml	5000 MPN / 100 Ml	--	5000 MPN / 100 Ml

Minnesota State Regulations, Water Standards, Minnesota Pollution Control Agency, St. Paul, Minnesota, 1973.
South Dakota Water Quality Standards and Criteria, Department of Environmental Protection, Pierre, South Dakota, 1974.
Values are mg/liter unless otherwise noted.

AD-A120 747 NATURAL RESOURCES STUDY TO DETERMINE CAUSES AND ALTERNATIVE SOLUTIONS TO T..(U) MIDWEST RESEARCH INST KANSAS CITY MO AUG 74 DACW37-74-C-0107

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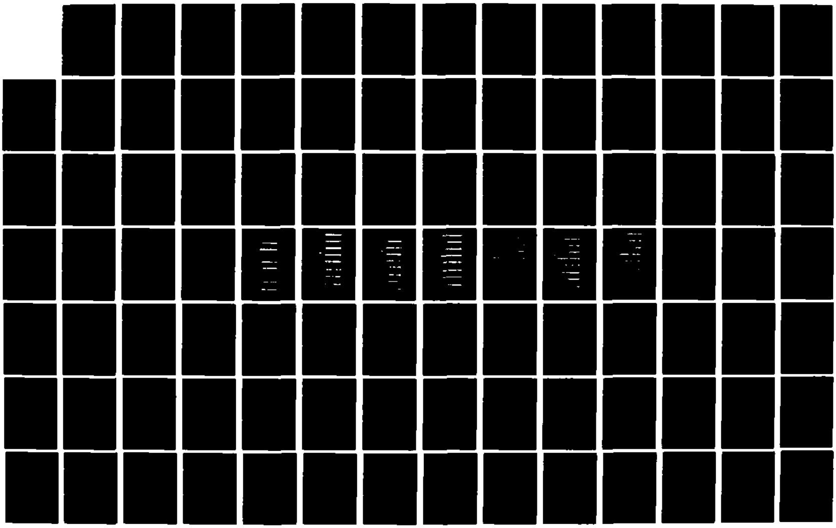

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MICROCOPY RESOLUTION TEST CHART
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MICROCOPY RESOLUTION TEST CHART
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Some differences in standards are also apparent for dissolved oxygen, temperature extremes, allowable ammonia nitrogen concentrations, and pH values. In some instances one state has assigned values to contaminants where the other has refrained from doing so.

c. Surface water quality: The quality of surface waters is quantified by various physical, chemical, and biological parameters such as: temperature; dissolved oxygen; nitrogen compounds; phosphates; hardness;dissolved and total solids; phenols; heavy metals, etc.; biochemical oxygen demand; and, various bacterial populations. The importance of these selected parameters are given under separate headings.

Temperature: High temperatures in water bodies (above 85-90°F for warm-water sport fish and 55°F for salmon and trout) are detrimental for spawning and egg development.[2/] Natural aquatic flora and other fauna may also be affected by increased water temperatures from industrial sources.

Dissolved oxygen: Oxygen is essential for an aquatic habitat. Minimum DO values are considered limiting at 5 mg/liter for warm-water sport fish and 6-7 mg/liter for trout waters.[2/] Available DO may be significantly reduced by sewage wastes or other organic waste effluents entering receiving waters and adversely affecting the aquatic fauna.

Specific conductance: Specific conductance yields a measure of a water's capacity to convey an electric current. This property is related to the total concentration of the ionized substances in water and the temperature at which the measurement is made. Most inorganic acids, bases, and salts are good conductors while organic compounds are very poor conductors.[110/]

Alkalinity: Alkalinity is determined by titration of a water sample with a standardized acid solution. The presence of both the bicarbonate and the carbonate ion are factors in the total alkalinity. Productive waterfowl habitats should have bicarbonate alkalinities of from 30-130 mg/liter.[2/]

Hardness: Water hardness is generally the result of the dissolved calcium and magnesium cations, although other divalent cations may be included in total hardness. Titration results are reported in mg/liter as $CaCO_3$.[110/]

Water for domestic use is considered hard with a value of 150 mg/liter and becomes objectionable for public water supplies at values of 300-500 mg/liter.[2/] No significance is relevant to water hardness and aquatic life.[2/]

pH: pH is the logarithm of the reciprocal of the hydrogen ion. The scale, 0-14, relates 0 as very acidic, 14 as very alkaline, and 7.0 as neutrality.

Most natural waters are between pH 4.0-9.0. Waters with a pH of between 6.0-9.0 are the most productive for fish and wildlife.2/

Turbidity: Turbidity is an expression of the optical properties of a sample of water which causes light to be scattered and absorbed rather than transmitted in a straight line through the sample. Silts and other sediments can be damaging to rubble type stream bottoms by filling interstices between gravel and stones. This eliminates spawning grounds for fish and the habitat of many aquatic insects and other invertebrate animals.

Where turbidities exceed 100 JTU the ability of sight feeding fish to capture prey is reduced and fish growth retarded.2/

Kjeldahl nitrogen: Kjeldahl analyses include ammonia nitrogen and organic nitrogen and values are reported in mg/liter as N. These analyses are important in assessing pollution sources from human or animal origin.

Ammonia nitrogen: Ammonia is present in many surface waters and usually is a product of microbiological activity on organic materials. Its evidence in surface waters is sometimes accepted as evidence of sanitary pollution.

Nitrate and nitrite nitrogen: Nitrate nitrogen represents the highest oxidized form in the nitrogen cycle and normally reaches important concentrations in the final stages of biological oxidation. Runoff from agricultural lands may also contribute nitrate compounds. In excessive amounts, it contributes to methemoglobinemia in infants. A maximum limit of 45 mg/liter nitrate or about 10 mg/liter (N) has, therefore, been imposed on drinking water. Nitrites, a reduced form of nitrate, are sometimes combined in assay results as nitrites generally occur in small concentrations.

Total phosphates: Phosphate sources entering fresh waters are greatly the results of man's activities; sewage discharges, plant and animal processing wastes, and agricultural fertilizer manufacturing and spillage. As this element is essential for plant growth, excess concentrations can stimulate aquatic plant growth including algal blooms. The National Technical Advisory Committee2/ recommends a maximum concentration of 50 µg (0.050 mg/liter) for lakes and 100 µg (0.100 mg/liter) for streams.

Orthophosphate: This inorganic form of phosphate is the most soluble and primarily results from the use of detergent compounds where phosphate builders are used to enhance cleaning processes.

Total solids: Total solids contain both soluble and filterable materials. Filterable solids or settleable materials are of both organic and inorganic nature and causes siltation which adversely affects the normal aquatic flora and fauna. Heavy loads of filterable materials are generally carried by streams when runoff is encountered after excessive precipitation.

Total dissolved solids: TDS constitute the major portion of the total solids carried by surface waters. These soluble materials are both organic and inorganic substances. Both the nature and quantity of these materials can affect the potability and the productivity of surface waters.

Phenols: Phenols are waste products of oil refineries, coke plants, and some chemical manufacturing facilities. Concentrations in the order of 10-100 mg/liter in water are detectable by taste and odor. Concentrations of 1 mg/liter in water produces an objectionable taste following chlorination.

Toxic metals: Toxic metals may occur in some surface waters from natural sources but usually are the result of industrial pollution. Their presence in surface waters may effect aquatic faunal communities, accumulate in individuals in a food chain, or provide a human and animal health hazard in drinking water.

Pesticides: The chlorinated hydrocarbons are deleterious to animal life in and out of water. Insoluble in water, the chlorinated hydrocarbons settle to the bottom and are taken up by organic matter or animal life. The animals near the end of the food chain, such as fish and birds, concentrate the chlorinated hydrocarbons in their fatty tissues and vital organs. Toxic levels vary with different species. Partial dechlorination of chlorinated hydrocarbons by fish and birds results in compounds which may be more or less toxic than the original compound. The amount of dechlorinated hydrocarbons present is a possible indication of how recently the animal absorbed the contaminant.

Radioactivity: Radiation in water and waste-water originates from natural and artificial or man-made sources. The development of nuclear science and its application to power development, industrial applications, and industrial uses require that attention be given to the assessment of the resulting degree of environmental radioactive contamination. It is important to provide adequate warning of unsafe conditions so that

proper precautions can be taken. Both alpha and beta particles are measured in surface and ground waters.

BOD: The biochemical oxygen demand is an empirical test to determine the relative amount of biological oxidizable materials in water or waste-water at the time of collection. A 5-day incubation period has been accepted as a standard procedure.

Fecal coliform count: Bacteriological analysis for fecal coliforms provides an assay for viable fecal coliforms and also a relative index as to the amount of fecal pollution from either human or animal sources.

Fecal streptococci counts: Fecal streptococci in conjunction with fecal coliform assays provide information useful in predicting whether the fecal contamination is of human or animal origin. If the ratio of fecal coliform to fecal streptococci counts are about 4:1, the source is very probably human, while a ratio of about 0.7:1 or less indicates animal fecal pollution.[111/]

The most meaningful data for analyzing water quality is that which has been generated from various sampling stations on the same date using the same parameters for evaluations and periodically sampled to cover seasonal variations in quality. From this optimum viewpoint, the most pertinent data are that generated by the Dorand Engineering Services for the Otter Tail Power Company and the Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon. Data from these studies, although of a more recent time period, are included in the survey and analysis.

(1) Whetstone and Minnesota River data analyses: Data presented on this segment of the watershed includes studies made by the Otter Tail Power Company (1971-74); studies by the Eutrophication Survey Branch of EPA (1972-73); and retrieval data obtained from the EPA Storet Bank (1960-72).

Area maps and corresponding coded sampling stations are shown in Figures 6 and 7, respectively, for the Otter Tail Power and the Eutrophication Survey Branch studies. Data is presented in Tables 36 and 37 for the Otter Tail Power study; in Tables 38 and 39 for the Eutrophication Survey Branch study; and Tables 40, 41, and 42 for the EPA Storet Retrieval Data.

Analysis of pertinent data was made with reference to standards set by the states of South Dakota (see Appendix G) and Minnesota (see Appendix H) where this stream was sampled in the respective states.

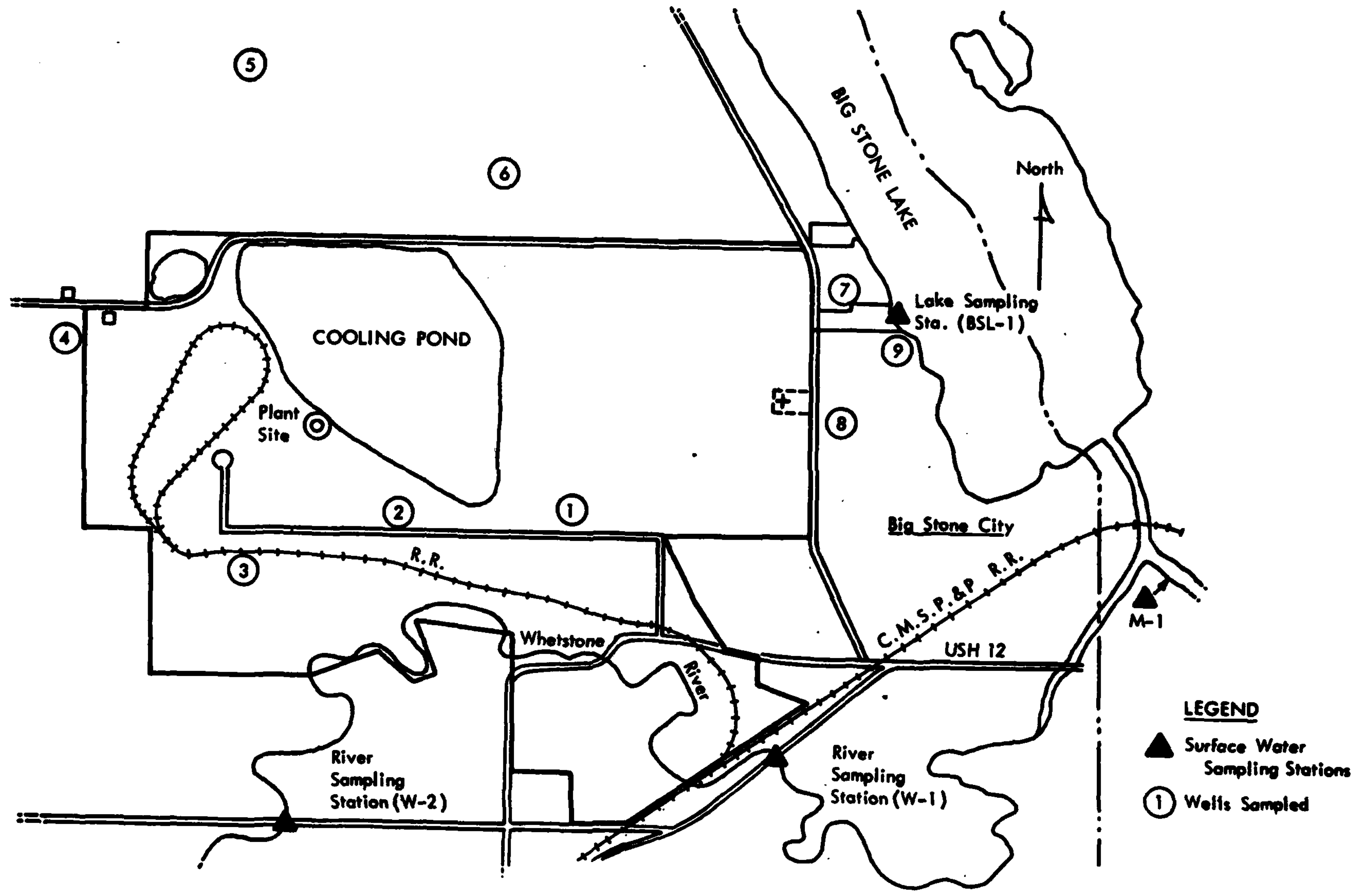

Figure 6 - Sampling Stations for the Otter Tail Power Plant Survey Near Big Stone City, South Dakota

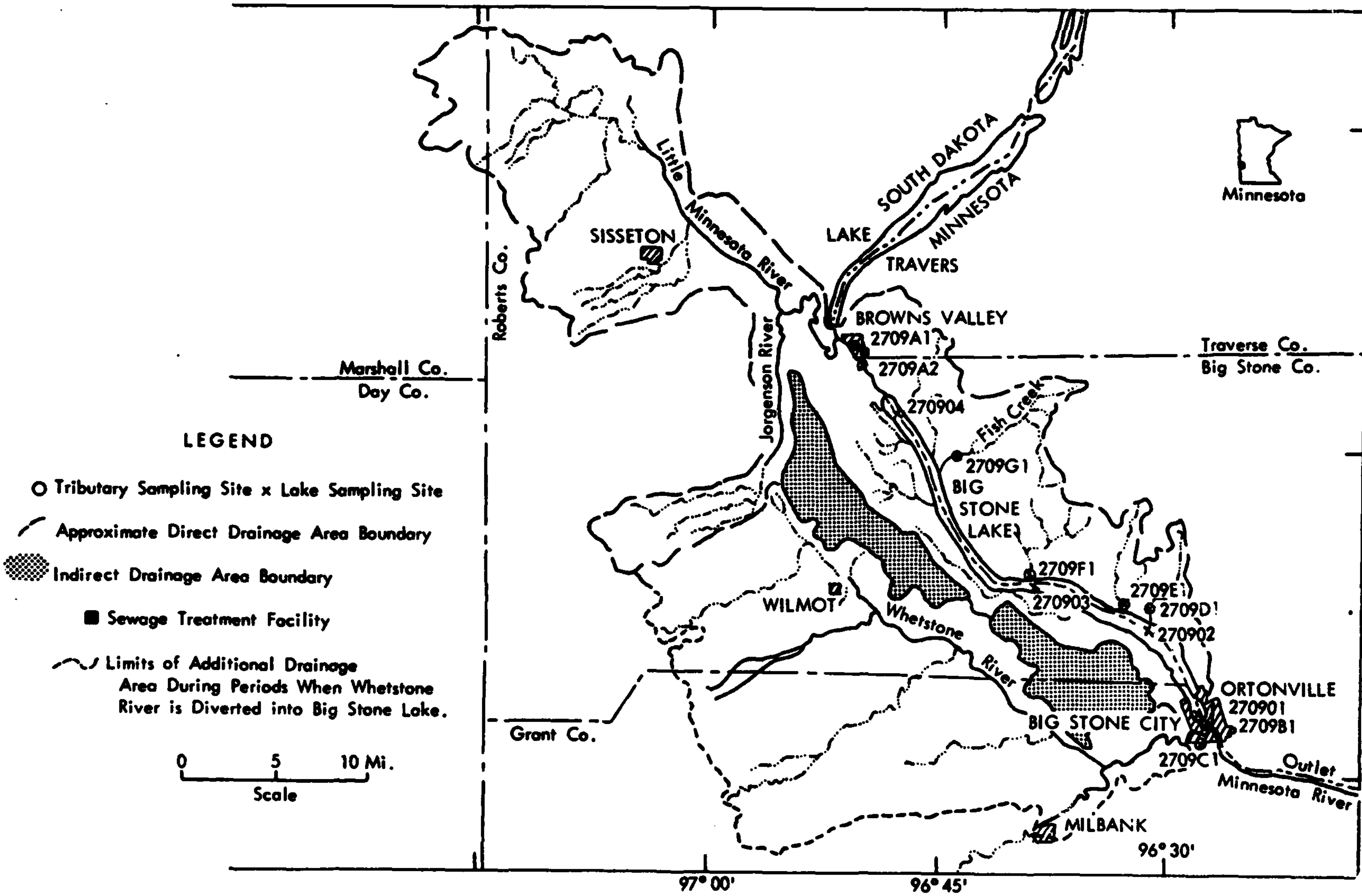

Figure 7 - Sampling Stations on Big Stone Lake and Its Tributaries--EPA

TABLE 36

WATER QUALITY DATA FROM WHETSTONE RIVER SAMPLING STATION W-1 - MONTHLY PROGRESSION

Station		Temperature (°F)	pH (units)	Conductivity (µmhos/cm)	Total Hardness as $CaCO_3$ (mg/ℓ)	Calcium Hardness as $CaCO_3$ (mg/ℓ)	Total Alkalinity as $CaCO_3$ (mg/ℓ)	Chlorides as Cl^- (mg/ℓ)	Sulfates as $SO_4^=$ (mg/ℓ)	Total Phosphorus as P (mg/ℓ)	Nitrate Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)
(W-1)	11-30-71	30	8.0	1,315	650	410	290	16	465	0.13	0.8	0.28
	12-29-71	29	7.7	1,545	900	500	367	22	560	0.27	1.1	0.44
	2- 1-72	31	8.0	1,430	720	440	360	29	460	0.45	1.2	1.00
	3- 2-72	30	7.6	1,040	620	400	342	39	340	0.82	1.3	0.14
	4- 3-72	37	8.1	940	550	360	334	9	340	0.14	0.8	0.25
	5-15-72	62	7.9	789	390	220	164	5	204	0.23	0.7	0.26
	6-14-72	69	8.3	1,125	550	350	292	3	324	0.14	0.6	0.15
	7-17-72	68	8.1	942	430	310	252	9	262	0.22	0.4	0.09
	8- 9-72	61	8.8	1,030	510	310	262	14	270	0.20	0.5	0.10
	9-12-72	61	8.1	1,162	530	330	280	27	260	0.25	0.1	0.18
	10-17-72	36	8.2	1,210	490	370	288	33	285	0.50	0.1	0.05
	11-14-72	30	8.2	1,230	550	390	286	21	340	0.12	0.6	0.16
	12-18-72	32	7.6	1,500	660	460	346	31	400	0.27	1.4	0.32
	1-16-73	34	7.6	1,485	640	450	356	36	350	0.37	2.6	0.00
	2-19-73	33	7.6	1,440	640	390	330	28	364	0.50	0.2	0.16
	3-21-73	46	8.1	1,015	570	320	236	10	236	0.18	0.8	0.25
	4-24-73	45	8.2	1,320	580	370	258	6	540	0.17	0.1	0.27
	5-21-73	71	8.2	1,210	540	340	268	22	350	0.10	0.0	0.17
	6-18-73	73	8.3	1,200	520	330	284	14	350	0.17	0.1	0.24
	7-16-73	79	8.1	1,110	500	300	274	27	270	0.18	0.0	0.12
	8-13-73	78	8.0	1,090	400	250	240	35	278	0.13	0.0	0.19
	9-10-73	70	8.0	1,045	450	260	276	40	260	0.18	0.0	0.20
	10- 8-73	63	7.8	1,156	410	290	282	42	304	0.14	0.0	0.24
	11- 5-73	36	8.0	1,076	510	310	308	44	264	0.15	0.1	0.24
	12- 5-73	32	8.0	1,255	580	250	322	47	324	0.30	0.7	0.14
	1-21-74	32	7.8	1,537	730	600	398	56	392	1.55	0.0	2.80
	2-25-74	34	7.7	1,376	589	362	372	49	322	1.24	0.2	2.90
	3-25-74	35	7.9	1,101	533	317	261	25	358	0.78	0.6	1.70

TABLE 36 (Concluded)

Station	Kjeldahl Nitrogen as N (mg/ℓ)	Total Residue (mg/ℓ)	Total Suspended Matter (mg/ℓ)	DO (mg/ℓ)	BOD (mg/ℓ)	Turbidity (% Trans.)	Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Sodium as Na (mg/ℓ)
(W-1) 11-30-71	0.9	1,034	5	13.1	2	13.0	140	<3	--
12-29-71	1.4	1,249	1	11.7	2	10.5	270	27	--
2- 1-72	1.0	1,070	5	10.0	1	8.6	160	23	--
3- 2-72	1.6	1,042	4	11.9	2	3.2	1,600	49	--
4- 3-72	0.8	760	16	12.0	5	3.9	<5	<3	--
5-15-72	1.6	753	118	7.8	6	27.0	3,600	1,900	--
6-14-72	0.9	888	22	7.4	3	9.0	2,600	60	--
7-17-72	1.2	760	26	8.1	8	17.0	800	40	--
8- 9-72	1.0	836	21	10.1	3	15.0	20,000	160	--
9-12-72	0.9	806	32	9.8	4	14.0	4,000	240	--
10-17-72	0.6	895	8	13.5	3	6.2	40	<3	--
11-14-72	0.8	889	6	16.1	2	8.5	280	30	--
12-18-72	0.5	1,051	9	11.2	4	4.6	30	30	--
1-16-73	0.3	1,036	2	10.5	3	14.0	120	6	63
2-19-73	1.4	924	7	9.1	3	2.8	-	-	56
3-21-73	1.0	769	19	11.7	4	4.2	65	6	33
4-24-73	1.2	938	7	11.5	5	16.0	30	27	60
5-21-73	1.4	919	12	10.0	5	16.0	50	47	51
6-18-73	1.4	900	32	9.9	6	9.0	340	100	50
7-16-73	1.9	870	38	10.5	6	10.0	300	230	59
8-13-73	1.2	782	51	9.7	6	11.0	2,400	370	66
9-10-73	1.2	884	33	9.7	6	10.0	300	240	69
10- 8-73	1.9	892	22	6.5	3	4.0	35	23	69
11- 5-73	1.2	869	7	13.4	3	3.5	35	3	72
12- 5-73	1.4	1,006	11	15.1	3	6.0	15	<3	93
1-21-74	2.9	1,126	4	7.0	1	6.0	<5	<3	76
2-25-74	3.3	982	5	8.6	4	3.0	45	3	65
3-25-74	2.7	820	22	11.5	3	2.0	20	<3	62

Source: Water Monitoring Program for Otter Tail Power Co., Dorand Engineering Services, Brookings, South Dakota, 1971-74.

TABLE 37

WATER QUALITY DATA FROM WHETSTONE RIVER SAMPLING STATION W-2 - MONTHLY PROGRESSION

Station		Temperature (°F)	pH (units)	Conductivity (μmhos/cm)	Total Hardness as $CaCO_3$ (mg/ℓ)	Calcium Hardness as $CaCO_3$ (mg/ℓ)	Total Alkalinity as $CaCO_3$ (mg/ℓ)	Chlorides as Cl^- (mg/ℓ)	Sulfates as $SO_4^=$ (mg/ℓ)	Total Phosphorus as P (mg/ℓ)	Nitrate Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)
(W-2)	11-30-71	30	8.0	1,330	670	420	293	15	480	0.12	0.5	0.30
	12-29-71	30	7.8	1,545	840	520	363	20	565	0.27	0.6	0.40
	2-1-72	30	7.4	1,440	700	420	362	35	430	0.54	0.8	1.30
	3-2-72	30	7.6	1,465	680	460	354	44	420	0.96	1.2	0.14
	4-3-72	34	7.5	1,045	500	340	336	8	305	0.13	0.7	0.30
	5-15-72	56	7.8	779	350	230	166	5	190	0.27	0.7	0.28
	6-14-72	66	8.2	1,130	560	350	290	6	290	0.17	0.4	0.09
	7-17-72	67	8.0	937	460	310	254	11	194	0.25	0.2	0.12
	8-9-72	58	8.2	1,130	490	310	294	15	250	0.23	0.2	0.13
	9-12-72	59	8.3	1,160	460	350	288	26	265	0.20	0.0	0.10
	10-17-72	35	8.2	1,310	540	410	300	49	310	0.10	0.0	0.04
	11-14-72	29	8.1	1,250	540	370	290	22	360	0.15	0.3	0.23
	12-18-72	32	7.6	1,560	650	450	360	31	400	0.32	1.0	0.33
	1-16-73	32	7.6	1,495	660	380	338	37	360	0.54	2.62	0.00
	2-19-73	32	7.6	1,360	670	400	334	30	364	0.62	0.4	0.90
	3-21-73	39	8.0	1,030	490	320	232	6	238	0.20	0.5	0.28
	4-24-73	45	8.2	1,210	570	360	256	14	550	0.15	0.1	0.20
	5-21-73	65	8.0	1,230	540	340	270	16	320	0.13	0.0	0.23
	6-18-73	72	8.1	1,170	540	330	292	17	340	0.21	0.1	0.23
	7-16-73	69	8.1	1,110	490	320	292	29	290	0.22	0.0	0.17
	8-13-73	71	8.2	1,025	400	270	278	34	236	0.18	0.0	0.20
	9-10-73	72	8.1	1,080	420	280	290	38	322	0.22	0.0	0.24
	10-8-73	63	8.0	1,176	440	290	316	51	276	0.14	0.0	0.19
	11-5-73	33	8.1	1,180	490	305	298	41	224	0.21	0.2	0.15
	12-5-73	32	8.0	1,275	600	340	324	47	324	0.27	0.4	0.25
	1-21-74	32	7.8	1,537	770	638	420	57	360	1.63	0.0	3.10
	2-25-74	32	7.6	1,345	560	341	383	48	341	1.64	0.0	3.30
	3-25-74	33	7.9	1,101	490	307	258	27	330	0.89	0.2	1.60

TABLE 37 (Concluded)

Station		Kjeldahl Nitrogen as N (mg/ℓ)	Total Residue (mg/ℓ)	Total Suspended Matter (mg/ℓ)	DO (mg/ℓ)	BOD (mg/ℓ)	Turbidity (% Trans.)	Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Sodium as Na (mg/ℓ)
(W-2)	11-30-71	0.9	1,051	8	12.7	1	15.5	430	40	--
	12-29-71	1.5	1,211	2	11.5	1	11.0	120	83	--
	2-1-72	1.7	1,097	10	9.1	2	5.4	110	10	--
	3-2-72	1.9	1,129	6	12.1	2	3.2	175	33	--
	4-3-72	2.2	773	17	11.8	3	4.3	<5	6	--
	5-15-72	1.6	756	124	7.3	5	29.0	2,900	1,400	--
	6-14-72	0.9	925	22	9.2	4	16.0	800	100	--
	7-17-72	1.0	765	27	6.7	5	22.0	200	80	--
	8-9-72	1.0	836	26	8.4	4	8.0	320	30	--
	9-12-72	0.9	837	54	8.1	5	12.0	4,500	350	--
	10-17-72	0.6	959	9	10.6	3	6.2	15	6	--
	11-14-72	0.8	900	9	14.0	2	7.8	450	50	--
	12-18-72	0.5	1,066	6	9.4	4	4.0	45	10	--
	1-16-73	0.3	1,051	3	9.2	4	12.0	40	20	63
	2-19-73	1.0	1,056	6	9.5	3	2.5	--	--	56
	3-21-73	1.1	779	22	11.4	4	3.2	40	33	34
	4-24-73	0.9	944	9	11.0	3	11.0	20	13	59
	5-21-73	1.4	912	12	7.3	4	20.0	150	120	51
	6-18-73	1.1	932	34	6.3	5	13.0	200	50	52
	7-16-73	1.5	888	41	6.1	8	13.0	400	110	60
	8-13-73	1.2	862	38	5.9	4	7.0	400	120	69
	9-10-73	1.0	862	25	7.1	4	9.0	200	67	71
	10-8-73	1.9	879	30	6.4	3	5.0	50	50	78
	11-5-73	1.0	854	4	12.4	4	3.5	25	6	75
	12-5-73	1.9	970	13	16.1	3	6.0	30	3	81
	1-21-74	3.5	1,149	7	3.9	3	6.0	10	<3	76
	2-25-74	4.0	958	6	5.0	5	3.0	30	3	69
	3-25-74	2.3	812	14	10.4	3	2.0	15	<3	65

Source: Water Monitoring Program for Otter Tail Power Company, Dorand Engineering Services, Brookings, South Dakota, 1971-74.

TABLE 38

WATER QUALITY DATA FOR WHETSTONE RIVER NEAR BIG STONE CITY, SOUTH DAKOTA, STATION 2709C1

Date	$NO_2 + NO_3$, Total as N (mg/ℓ)	Kjeldahl Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Orthophosphate as P (mg/ℓ)	Total Phosphate as P (mg/ℓ)
11/19/72	1.260	1.600	0.160	0.117	0.320
03/18/73	1.360	2.000	0.330	0.105	0.250
04/02/73	0.294	1.600	0.220	0.091	0.150
04/15/73	0.011	1.150	0.013	0.050	0.115
05/01/73	0.027	3.150	0.060	0.037	0.080
05/19/73	<0.010	0.880	0.018	0.027	0.100
06/03/73	0.390	1.100	0.105	0.007	0.165
07/12/73	<0.010	3.300	0.140	0.039	0.130
08/05/73	0.017	1.300	0.036	0.040	0.185
09/18/73	<0.010	2.200	0.032	0.056	0.290
Maximum	12.600	3.300	0.330	1.470	3.200
Minimum	0.011	0.880	0.013	0.007	0.080
Mean	2.100	1.828	0.111	0.192	0.466

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon (1974).

TABLE 39

WATER QUALITY DATA FOR MINNESOTA RIVER--
BIG STONE LAKE AT DAM - SW OF
ORTONVILLE, MINNESOTA, STATION 2709 B1

Date	$NO_2 + NO_3$, Total as N (mg/ℓ)	Kjeldahl Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Orthophosphate as P (mg/ℓ)	Total Phosphate as P (mg/ℓ)
10/14/72	0.068	2.450	0.105	0.011	0.168
11/19/72	0.130	1.300	0.210	0.014	0.050
12/16/72	0.300	1.600	0.440	0.052	0.100
01/13/73	0.315	2.000	0.670	0.098	0.165
02/10/73	0.138	2.200	0.750	0.042	0.090
03/18/73	0.380	1.890	0.680	0.056	0.125
04/02/73	<0.010	2.300	0.015	0.026	0.190
04/15/73	<0.010	2.100	0.012	0.025	0.210
05/01/73	0.018	1.640	0.138	0.056	0.175
05/19/73	0.056	1.540	0.198	0.038	0.130
06/03/73	0.390	2.310	0.120	0.092	0.125
07/12/73	0.048	1.980	0.313	0.070	0.170
08/05/73	0.140	2.000	0.450	0.134	0.255
09/18/73	0.031	1.600	0.057	0.126	0.195
Maximum	.390	2.450	0.750	0.134	0.255
Minimum	.018	1.300	0.012	0.011	0.050
Mean	.168	1.922	0.297	0.060	0.153

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon (1974).

TABLE 40

WATER QUALITY DATA FOR WHETSTONE RIVER NEAR BIG STONE CITY, SOUTH DAKOTA

Parameters	No. of Samples	Mean	Maximum	Minimum	Period Covered
Water Temperature (°F)	26	43.7	74.8	32.0	10/18/66-6/4/69
Stream Flow (cfs)	28	127.9	2,740.0	1.3	3/19/61-6/4/69
Dissolved Oxygen (mg/ℓ)	1	8.2	8.2	8.2	1/12/67
pH (units)	30	--	8.5	6.6	10/12/60-6/4/69
Color (platinum, cobalt units)	18	10.66	40.0	4.0	10/12/60-7/2/68
Conductivity (μmhos/cm)	30	1,108.27	1,780.0	218.0	10/12/60-6/4/69
Alkalinity, Total as $CaCO_3$ (mg/ℓ)	26	289.42	554.0	138.0	1/12/67-6/4/69
Alkalinity, as HCO_3 (mg/ℓ)	30	337.83	676.0	83.0	10/12/60-6/4/69
Alkalinity, as CO_3 (mg/ℓ)	30	0.53	9.0	0.0	10/12/60-6/4/69
Nitrate, as (N) (mg/ℓ)	8	0.84	3.4	0.0	10/3/68-6/4/69
Orthophosphates , PO_4 (mg/ℓ)	19	0.79	6.1	0.14	1/12/67-6/4/69
Total Hardness as $CaCO_3$ (mg/ℓ)	30	524.17	905.0	90.0	10/12/60-6/4/69
Noncarbonate Hardness, as $CaCO_3$ (mg/ℓ)	30	246.23	397.0	22.0	10/12/60-6/4/69
Calcium, as Ca (mg/ℓ)	30	122.57	215.0	27.0	10/12/60-6/4/69
Magnesium, as Mg (mg/ℓ)	30	53.28	90.0	5.5	10/12/60-6/4/69
Sodium, Dissolved as Na (mg/ℓ)	30	51.85	94.0	2.5	10/12/60-6/4/69
Potassium, Dissolved as K (mg/ℓ)	30	8.39	12.0	5.0	10/12/60-6/4/69
Chloride, as Cl (mg/ℓ)	30	28.99	62.0	0.0	10/12/60-6/4/69
Total Sulfate, as SO_4 (mg/ℓ)	30	307.4	468.0	27.0	10/12/60-6/4/69
Fluoride, Dissolved as F (mg/ℓ)	23	0.26	0.50	0.10	10/12/60-6/4/69
Silica, Dissolved (mg/ℓ)	23	16.24	34.0	5.3	10/12/60-6/4/69
Boron, Dissolved as B (μg/ℓ)	29	180.69	330.0	40.0	10/12/60-6/4/69
Cadmium, Dissolved as Cd (μg/ℓ)	1	0.0	0.0	0.0	10/6/67-10/6/67
Chromium, Dissolved as Cr (μg/ℓ)	1	0.0	0.0	0.0	10/6/67-10/6/67
Chromium, Total as Cr (μg/ℓ)	3	0.0	0.0	0.0	1/12/67-9/13/67
Cobalt, as Co (μg/ℓ)	2	0.0	0.0	0.0	1/12/67-3/30/67
Copper, as Cu (μg/ℓ)	4	0.0	0.0	0.0	1/12/67-10/6/67
Iron, Total as Fe (μg/ℓ)	13	59.23	200.0	10.0	10/6/67-7/2/68
Iron, Dissolved as Fe (μg/ℓ)	2	185.0	360.0	10.0	5/2/69-6/4/69
Lead, Dissolved as Pb (μg/ℓ)	2	0.0	0.0	0.0	1/12/67-3/30/67
Manganese, as Mn (μg/ℓ)	21	252.38	730.0	20.0	10/12/60-7/2/68
Manganese, Dissolved as Mn (μg/ℓ)	2	105.0	120.0	90.0	5/2/69-6/4/69
Nickel, Dissolved as Ni (μg/ℓ)	2	5.0	10.0	0.0	1/12/67-3/30/67
Strontium, Dissolved as Sr (μg/ℓ)	2	560.0	760.0	360.0	1/12/67-3/30/67
Zinc, Dissolved as Zn (mg/ℓ)	4	45.0	140.0	0.0	1/12/67-10/6/67
Aluminum, Total as Al (mg/ℓ)	10	530.0	1,200.0	0.0	1/12/67-7/2/68
Dissolved Solids (mg/ℓ)	15	815.0	1,290.0	544.0	10/6/67-6/4/69
Dissolved Solids (tons/day)	22	37.3	268.0	2.8	1/12/67-6/4/69
Dissolved Solids (tons/acre/ft)	26	1.14	1.84	0.5	1/12/67-6/4/69
Suspended Sediment (mg/ℓ)	3	96.0	202.0	10.0	10/18/66-3/30/67
Suspended Sediment (tons/day)	3	18.05	48.0	0.16	10/18/66-3/30/67
Fecal Coliforms MF (count/100 ml)	21	250.38	2,200.0	0.00	4/17/68-10/26/72
Fecal Streptococci (count/100 ml)	18	559.22	4,500.0	0.0	7/9/69-10/26/72

Source: Environmental Protection Agency, Storet Data, April 15, 1974.

TABLE 41

WATER QUALITY DATA FROM MINNESOTA RIVER SAMPLING STATION M-1 - MONTHLY PROGRESSION

Station		Temperature (°F)	pH (units)	Conductivity (μmhos/cm)	Total Hardness as $CaCO_3$ (mg/ℓ)	Calcium Hardness as $CaCO_3$ (mg/ℓ)	Total Alkalinity as $CaCO_3$ (mg/ℓ)	Chlorides as Cl^- (mg/ℓ)	Sulfates as $SO_4^=$ (mg/ℓ)	Total Phosphorus as P (mg/ℓ)	Nitrate Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)
(M-1)	11-30-71	31	8.0	1,270	670	400	285	15	460	0.12	0.3	0.32
	12-29-71	32	7.8	1,380	680	400	298	19	485	0.16	0.4	0.43
	2-1-72	33	7.9	1,185	520	320	236	18	420	0.11	0.1	0.40
	3-2-72	32	7.8	1,235	580	340	236	19	390	0.11	0.4	0.10
	4-3-72	49	8.3	959	430	270	182	11	270	0.13	0.2	0.35
	5-15-72	61	7.9	784	330	240	172	5	190	0.33	0.5	0.32
	6-14-72	70	8.4	895	390	240	176	7	240	0.11	0.1	0.32
	7-17-72	69	8.2	920	410	320	238	11	216	0.20	0.0	0.12
	8-9-72	64	8.1	978	410	240	212	10	220	0.22	0.0	0.20
	9-12-72	63	8.1	1,160	480	300	280	20	240	0.12	0.0	0.08
	10-17-72	36	8.2	1,200	530	320	286	22	270	0.10	0.0	0.06
	11-14-72	30	8.1	1,230	530	350	286	11	330	0.12	0.1	0.14
	12-18-72	34	6.9	1,560	670	450	340	31	400	0.30	0.3	0.57
	1-16-73	34	7.6	1,465	520	390	354	36	360	0.35	2.5	0.04
	2-19-73	38	7.7	1,260	540	290	238	20	320	0.02	0.2	0.78
	3-21-73	45	7.8	930	460	220	170	9	220	0.13	0.1	0.56
	4-24-73	44	8.2	1,190	540	340	254	15	385	0.20	0.0	0.18
	5-21-73	65	8.1	1,095	530	340	268	18	315	0.19	0.0	0.23
	6-18-73	73	8.2	1,160	540	320	270	15	346	0.20	0.0	0.26
	7-16-73	78	8.2	1,100	480	260	252	26	300	0.15	0.0	0.12
	8-13-73	78	8.2	1,110	410	250	242	34	288	0.24	0.0	0.20
	9-10-73	73	7.5	995	370	240	182	20	228	0.23	0.0	0.28
	10-8-73	64	8.0	1,166	430	270	282	44	264	0.01	0.0	0.13
	11-5-73	37	7.6	1,175	500	309	304	38	304	0.03	0.0	0.15
	12-5-73	32	7.7	1,175	580	240	314	50	294	0.18	0.1	0.10
	1-21-74	32	7.5	1,505	803	508	399	49	352	0.94	0.0	2.08
	2-25-74	34	7.6	1,308	568	351	332	51	340	1.43	0.0	2.90
	3-25-74	34	7.9	1,141	502	319	256	12	342	0.65	0.1	1.45

TABLE 41 (Concluded)

Station		Kjeldahl Nitrogen as N (mg/ℓ)	Total Residue (mg/ℓ)	Total Suspended Matter (mg/ℓ)	DO (mg/ℓ)	BOD (mg/ℓ)	Turbidity (% Trans.)	Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Sodium as Na (mg/ℓ)
(M-1)	11-30-71	1.0	1,045	5	12.9	1	13.5	330	3	--
	12-29-71	1.3	1,076	5	11.3	2	9.5	45	13	--
	2-1-72	1.2	927	15	12.1	2	4.2	40	<3	--
	3-2-72	1.4	967	6	11.9	2	4.6	17	2	--
	4-3-72	0.8	693	10	11.4	4	4.7	<5	<3	--
	5-15-72	1.6	797	202	7.7	6	17.0	2,600	900	--
	6-14-72	1.2	692	38	9.3	4	13.0	300	30	--
	7-17-72	1.1	719	20	8.6	5	13.0	200	50	--
	8-9-72	1.5	762	23	8.9	7	13.0	300	50	--
	9-12-72	0.9	799	18	6.2	5	10.0	3,200	60	--
	10-17-72	0.6	875	10	11.2	4	10.5	30	<3	--
	11-14-72	0.6	895	5	16.7	2	5.3	20	<3	--
	12-18-72	1.0	881	4	10.0	2	4.6	50	6	--
	1-16-73	1.0	1,047	2	9.7	4	11.6	75	18	54
	2-19-73	1.4	894	10	6.3	2	1.5	--	--	53
	3-21-73	1.8	696	19	9.0	4	2.1	20	<3	41
	4-24-73	0.9	904	4	10.6	3	10.0	25	<3	47
	5-21-73	1.3	946	37	7.0	6	29.0	200	67	51
	6-18-73	1.8	914	24	8.2	7	9.0	500	200	53
	7-16-73	1.9	867	21	9.7	9	7.0	380	16	59
	8-13-73	1.0	861	29	7.7	4	9.0	180	70	67
	9-10-73	1.4	833	22	9.4	4	7.0	100	20	64
	10-8-73	1.6	847	30	6.0	1	4.0	25	3	63
	11-5-73	0.9	869	4	12.5	3	2.5	30	<3	63
	12-5-73	0.9	978	9	15.7	3	2.0	<5	<3	72
	1-21-74	2.6	1,143	10	6.8	2	2.0	30	6	68
	2-25-74	3.6	981	11	9.0	3	3.0	20	17	66
	3-25-74	2.9	843	5	11.1	4	1.0	25	<3	50

Source: Water Monitoring Program for Otter Tail Power Company, Dorand Engineering Services, Brookings, South Dakota, 1971-74.

TABLE 42

WATER QUALITY DATA FOR LITTLE MINNESOTA RIVER NEAR PEEVER, SOUTH DAKOTA

Date	Temperature °F	Specific Conductance (μ mhos/cm)	DO (mg/ℓ)	pH (Units)	Total Alkalinity $CaCO_3$ (mg/ℓ)	Residue Total (mg/ℓ)	Dissolved Solids (mg/ℓ)	NO_3-N (mg/ℓ)	Total Hardness $CaCO_3$ (mg/ℓ)	Calcium $CaCO_3$ (mg/ℓ)
4/17/68	--	1,190	--	--	204	1,005	--	0.00	557	138.2
7/23/68	64.0	1,420	--	--	308	1,254	--	0.00	723	184.2
4/7/69	39.0	340	10.8	--	97	765	217	0.15	160	44.1
7/9/69	76.0	1,210	9.6	8.00	248	993	--	--	553	136.2
3/16/70	33.8	1,230	8.2	7.20	276	993	987	0.00	547	172.2
7/6/70	77.0	1,320	7.8	7.90	288	1,100	1,075	0.45	644	170.2
10/21/70	48.0	1,470	8.3	7.80	315	1,228	1,206	0.00	701	192.2
12/1/70	34.7	1,580	10.3	7.50	328	1,345	1,322	0.00	742	196.2
2/16/71	35.6	1,390	6.5	7.50	304	1,257	1,164	0.00	666	178.2
3/23/71	32.9	470	12.5	7.50	130	415	--	0.00	226	60.1
4/20/71	63.5	1,280	14.5	8.00	255	987	772	0.00	551	144.2
5/19/71	48.2	1,490	--	--	325	1,294	628	0.00	721	176.2
7/14/71	75.2	970	7.7	7.60	290	846	794	0.00	482	132.2
8/26/71	59.0	1,430	7.5	7.70	320	1,217	1,217	0.00	732	208.3
9/9/71	63.0	1,370	7.4	7.70	280	1.127	1,127	0.00	612	176.2
10/14/71	54.0	1,470	8.8	7.40	355	1,257	1,240	0.00	752	208.2
2/16/72	33.0	1,700	7.0	7.50	350	1,448	1,428	0.00	863	232.3
3/28/72	34.0	610	12.5	--	140	519	450	0.20	301	75.3
6/20/72	64.4	1,160	10.8	8.20	270	972	957	0.55	561	144.2
8/28/72	64.4	1,150	9.8	8.20	276	1,053	1,021	0.78	581	152.2
10/26/72	46.5	--	7.50	--	--	--	--	--	--	--

TABLE 42 (Concluded)

Date	Magnesium $CaCO_3$ (mg/ℓ)	Sodium Na (mg/ℓ)	Potassium K (mg/ℓ)	Chloride Cl (mg/ℓ)	Sulfate SO_4 (mg/ℓ)	Fluoride F (mg/ℓ)	Iron Fe (μg/ℓ)	Manganese Mn (μg/ℓ)	Fecal Coliform MF (Count/100 ml	Fecal Streptococci MF (Count/100 ml)
4/17/68	51.3	88.30	8.10	25	522	0.60	300	250.0	0	--
7/23/68	63.2	76.80	8.10	15	549	0.30	500	1,300.0	53	--
4/7/69	10.7	8.50	5.70	0	76	0.14	2,200	800.0	0	--
7/9/69	51.8	73.60	8.60	22	444	0.40	60	150.0	120	100
3/16/70	27.9	90.20	10.95	37	408	0.37	350	550.0	3	96
7/6/70	53.0	75.90	8.90	16	503	0.34	300	300.0	42	--
10/21/70	53.5	90.20	7.80	23	552	0.44	200	300.0	3	20
12/1/70	60.8	113.20	9.70	23	620	0.42	700	300.0	60	88
2/16/71	52.2	85.60	6.90	15	542	0.32	2,400	700.0	0	8
3/23/71	18.2	17.20	9.70	6	124	0.34	200	200.0	90	80
4/20/71	46.2	75.90	9.20	49	404	0.40	300	300.0	33	20
5/19/71	68.0	98.40	10.20	30	397	0.28	400	100.0	<3	36
7/14/71	36.4	46.00	6.80	9	354	0.28	500	400.0	210	80
8/26/71	51.0	74.50	8.40	17	532	0.21	600	500.0	60	28
9/9/71	41.3	98.40	8.80	31	486	0.26	700	400.0	40	24
10/14/71	55.9	84.00	8.80	17	554	0.21	800	450.0	6	52
2/16/72	68.0	94.00	9.00	24	655	0.25	800	800.0	<3	24
3/28/72	27.2	20.30	4.80	8	184	0.16	200	250.0	170	120
6/20/72	48.6	5.50	61.60	16	406	0.27	200	200.0	1,600	1,800
8/28/72	48.6	74.52	7.00	18	472	0.30	200	250.0	53	85
10/26/72	--	--	--	--	--	--	--	--	--	--

Source: Environmental Protection Agency, Storet Data (1974).

Temperature: All data shows compliance with the 90°F maximum set by each state (Table 35).

pH: Tolerance for pH is set for South Dakota at 6.3-9.0 and all data comply with both state's standards. A low value is reported at 6.6 (Table 40) near Big Stone City.

Specific conductance: In general, the waters of the Whetstone carry an extremely heavy load of dissolved inorganic materials as seen by conductivities in the range of 1,000 µmhos/cm. No standards apply to this measurement but extremely hard water is indicated where divalent-cations are involved.

Hardness: The Whetstone River water is extremely hard. For human consumption, hardness of 300-500 mg/liter is considered excessive.[2/]

Alkalinity: Alkalinity in the lower Whetstone River ranges is from 200-400 mg/liter. No state standards apply to this evaluation; however, waters with bicarbonate alkalinity of 30-130 mg/liter are productive waterfowl habitats.[2/] These waters are of the bicarbonate type.

Sulfates: Due to the geology of the area, sulfates are extremely high in the Whetstone River waters. No state standards apply to this parameter; however, a recommended upper limit is 1,000 mg/liter.[2/]

Total phosphorus: The phosphorus concentration in streams and lakes is considered a limiting factor for aquatic plant growth[2/] where other essential minerals and suitable conditions are present. Neither South Dakota nor Minnesota have quantitative standards for phosphates for the Whetstone River. However, the National Technical Advisory Committee[2/] recommends a maximum concentration of 0.100 mg/liter total phosphorus for streams or 0.050 mg/liter (P) phosphorus where streams enter lakes or reservoirs.

Monthly samplings for the Otter Tail Power Company (Tables 36, 37, and 40) show phosphate concentrations from about 2-30 times the 0.050 mg/liter recommended maximum limit. The highest concentrations observed in that study occurred the first 3 months in 1974.

Sampling by the Eutrophication Survey Branch, EPA (Table 38) showed a maximum (P) value of 3.200, minimum 0.080, and mean of 0.466 mg/liter for the Whetstone River and a maximum of 0.255, minimum of 0.050, and mean of 0.153 mg/liter for the Minnesota River (Table 39).

The excessive high phosphate level reported in November, 1972 (Table 38) was a result of near zero flow rate of the Whetstone River.[112] The only flow was reported to be from the Milbank, South Dakota, sewage treatment plant. The maximum value of 3.200 mg/liter total phosphorus is over 30 times the recommended maximum limit.

Orthophosphate: Storet data for the Whetstone River near Big Stone City (Table 40) provides data for orthophosphate only, which is the inorganic soluble form. Analyses between 1967-69 (Table 40) show a maximum value of 6.1, a minimum of 0.14, and a mean of 0.79 mg/liter calculated as (PO_4). Calculated on the basis of (P) for purposes of comparison, the maximum value would be 2.1, minimum 0.05, with a mean of 0.27 mg/liter as (P). The orthophosphate values are less than the total phosphate and that mean is 5 times the recommended level for streams entering lakes.

Orthophosphate analyses (Table 38) for the Whetstone River and (Table 39) for the Minnesota River are above federal recommended limits[2] with one 14-fold excess on one sampling date (Table 38).

Kjeldahl nitrogen: This evaluation includes both ammonia nitrogen and organic nitrogen and is indicative of pollution from plant or animal origin. Tables 36-39, and 41 show considerable concentrations of Kjeldahl nitrogen ranging from 0.3-4.0 mg/liter nitrogen as (N). Values for the Minnesota River (Table 39) show relatively constant concentrations over the 4 monthly sampling analyses.

Total nitrogen: Although not listed as a separate parameter in the tables, the parameter includes Kjeldahl nitrogen, nitrate, and nitrite nitrogen. A survey of data in Tables 36-38, and 41 reveals that the total nitrogen as N to total phosphate as P is a ratio of about 2:1. The one exception is evident in Table 38 (11-19-72) where nitrate and nitrite nitrogen are reported at an excessive value of 12.6 mg/liter (N). This value is due to a near zero flow in the Whetstone River with the only flow coming from the Milbank, South Dakota, sewage treatment plant. In this one instance the N:P ration is about 5:1. Although this ratio may vary, in natural waters the ratio is often 10:1 (N:P) and is considered a good guideline for normal conditions.[2]

The Minnesota River data (Table 39) show approximately a 10:1 ratio N:P although the phosphorus concentrations are above federal recommended levels.[2]

Ammonia as N: Both South Dakota and Minnesota have standards on the ammonia content of the Whetstone River (Table 35). In addition, the Minnesota standard on the Minnesota River (Tables 39 and 41)

for maximum allowable ammonia is 1.0 mg/liter (Appendix H). The ammonia concentration exceeded the South Dakota standards for each of the first 3 months in 1974 (Tables 36 and 37) and once in February, 1972 (Table 37). Minnesota standards were also exceeded for the Minnesota River in the first 3 months of 1974 (Table 41). However, data from Table 39 show compliance with Minnesota standards.

Total residue: The total residues (Tables 36, 37, and 41) range from about 700-1,500 mg/liter and because the suspended matter is relatively low, most of the residue is soluble material. These high values are primarily due to soluble inorganic salts already indicated by the total hardness and sulfate content of the Whetstone River water.

Suspended solids: South Dakota standards for the Whetstone River are 90 mg/liter maximum. Minnesota has no standards for this parameter (Table 35). These standards were slightly exceeded only once on 5-15-72 (Tables 36 and 37) and at least once between 1966-67 (Table 40).

Dissolved oxygen (DO): DO standards on the Whetstone River are shown in Table 35 for both states. Data in Tables 36, 37, 40, and 41 show that only one value, 3.9 mg/liter, was below standards (1-21-74, Table 37).

BOD: Neither state has standards on BOD for the Whetstone or Minnesota Rivers. Values shown in Tables 36, 37, and 40 are very acceptable.

Turbidity: Standards in Table 35 show a maximum value of 25 JTU for Minnesota and 50 JTU for South Dakota. South Dakota standards were not exceeded (Tables 36 and 37). Minnesota standards were exceeded slightly only once (5-21-73, Table 41) on the Minnesota River station.

Fecal coliforms: Standards for the Whetstone River for the two states are shown in Table 35. Minnesota is the most stringent with 200/100 ml sample. South Dakota allows a count of 1,000/100 ml sample. The South Dakota standard was exceeded once in 1972 (Tables 36 and 37) and at least once between 1968-72 (Table 40). Minnesota standards were exceeded once (Table 41).

Total coliforms: An excessive total coliform count was recorded on 8-9-72 (Table 36) which exceeds the South Dakota standards of 5,000/100 ml.

Total iron: South Dakota standards are 200 µg or 0.200 mg/liter (Table 35). Data from Table 40 show this parameter to be within the standards.

(2) Little Minnesota River data analyses: Data presented in this segment of the watershed includes the study by Eutrophication Survey Branch of EPA (1972-73) and retrieval data obtained from the Storet Bank (1968-72).

The location of sampling stations utilized by the Eutrophication Survey Branch are shown in Figure 7.

Analysis of the data was made with reference to South Dakota water quality standards and some recommended federal levels on certain parameters.

Temperature: Temperatures reported in Table 42 are all in compliance with South Dakota standards: a maximum of 90°F.

Specific conductance: Specific conductance values (Table 42) reflect extremely high concentrations of soluble inorganic materials. The average value is well over 1,000 µmhos/cm.

Dissolved oxygen (DO): The minimum standard of 5.0 mg/liter is stipulated by South Dakota. All reported DO values in Table 42 are well above the minimum standard.

pH: Values for pH (Table 42) are well within the range (6.3-9.0) stipulated by South Dakota. Values reported are 7.4-8.2.

Total alkalinity: Alkalinity for the Little Minnesota River (Table 42) ranges from 97-355 mg/liter as $CaCO_3$. These waters are in a comparable range of those of the lower Whetstone River. No state standards or federal recommendations apply for alkalinity.

Total residue: Total residue values are high, 415-1,448 mg/liter (Table 42). These values are comparable to those for the lower Whetstone River. These values are indicative of high concentrations of soluble salts and/or suspended materials.

Nitrate nitrogen (N): Nitrate nitrogen values (Table 42) are low or, much of the time, not detectable. However, a trend at this sampling station is for higher values occurring in the three sampling periods reported in 1972.

Values obtained by the Eutrophication Survey Branch (Tables 43 and 44) above and below the Brown's Valley, Minnesota, sewage treatment plant, respectively, show a definite relationship of sewage effluent entering the Little Minnesota River at those locations. The nitrate-nitrite (Tables 42 and 43) concentration (considered to be 95% nitrate) shows an increase of about two-fold as a result of sewage effluents.

No state standards apply for this parameter.

Kjeldahl nitrogen (N): The Kjeldahl procedure measures both organic and ammonia nitrogen and the effects of the sewage plant effluent entering the Little Minnesota River is apparent with about 1.5-fold increase in the mean value for Kjeldahl nitrogen (Tables 43 and 44).

No state standards apply for this parameter.

Ammonia nitrogen (N): Both South Dakota and Minnesota have maximum concentration standards of 1.0 and 1.5 mg/liter, respectively, for this parameter (Table 35). Standards for both states are met on samples above the sewage treatment plant (Table 43). However, on two sampling dates (January and February 1973, Table 44) the South Dakota standards were exceeded. The Minnesota standards were exceeded on one of those dates (see Table 35 for standards).

Orthophosphate (P): Orthophosphate is considered to occur in waters primarily as a result of detergent compounds in waste effluents. Water samples taken in the Little Minnesota River above and below Brown's Valley, Minnesota, sewage plant greatly magnify the effects of the sewage effluent (Tables 43 and 44). The mean value shows about a seven-fold increase in orthophosphate from samples below the sewage treatment plant.

No state standards apply to this parameter.

Total phosphates: Total phosphate concentrations are not covered by either South Dakota or Minnesota standards. However, sewage treatment (Minnesota maximum standards--1.0 mg/liter total phosphate) is stipulated. The federal recommendation for lakes, reservoirs, or streams entering these bodies of water is concentrations not greater than 0.050 mg/liter.[2/] A mean value (0.097 mg/liter) total phosphate above the sewage plant (Table 43) exceeds the recommended concentration (0.050 mg/liter). The concentration of total phosphate below the sewage treatment plant (0.527 mg/liter) (Table 44) is over five-fold that value obtained above the plant.

TABLE 43

WATER QUALITY DATA FOR THE LITTLE MINNESOTA RIVER AT BROWNS VALLEY, MINNESOTA ABOVE SEWAGE TREATMENT PLANT

Date	$NO_2 + NO_3$, Total as N (mg/ℓ)	Kjeldahl Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Orthophosphate as P (mg/ℓ)	Total Phosphate as P (mg/ℓ)
10/14/72	0.036	0.590	0.056	0.080	0.130
11/19/72	0.022	0.660	0.047	0.007	0.042
12/16/72	0.350	0.717	0.270	0.014	0.027
01/13/73	0.460	1.200	0.550	0.025	0.050
02/10/73	0.610	1.600	0.880	0.160	0.232
03/18/73	0.480	2.100	0.210	0.084	0.210
04/02/73	0.023	2.100	0.147	0.033	0.065
04/15/73	0.014	0.730	0.015	0.018	0.040
05/01/73	0.022	0.560	0.008	0.026	0.045
05/19/73	<0.010	1.800	0.079	0.021	0.050
06/03/73	0.390	1.800	0.365	0.099	0.170
07/12/73	0.126	1.760	0.115	0.066	0.105
08/05/73	0.084	1.050	0.100	0.044	0.105
09/18/73	0.029	1.200	0.075	0.039	0.090
Maximun	0.610	2.100	0.880	0.160	0.232
Minimum	0.014	0.560	0.008	0.007	0.027
Mean	0.203	1.276	0.208	0.051	0.097

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon (1974).

TABLE 44

WATER QUALITY DATA FOR LITTLE MINNESOTA RIVER--
0.9 MILE SE OF BROWN'S VALLEY, MINNESOTA - STATION 2709A2
(BELOW SEWAGE TREATMENT)

Date	$NO_2 + NO_3$, Total as N (mg/ℓ)	Kjeldahl Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Orthophosphate as P (mg/ℓ)	Total Phosphate as P (mg/ℓ)
10/14/72	0.480	3.300	0.338	0.323	0.600
11/19/72	0.200	0.760	0.252	0.200	0.294
12/16/72	0.410	2.200	0.670	0.270	0.530
01/13/73	0.420	3.800	2.000	0.400	0.730
02/10/73	0.630	3.000	1.370	0.290	0.460
03/18/73	0.510	1.760	0.340	0.105	0.240
04/02/73	0.035	1.150	0.065	0.056	0.135
04/15/73	0.035	0.865	0.075	0.044	0.085
05/01/73	0.067	1.300	0.100	0.063	0.110
05/19/73	0.031	0.920	0.068	0.073	0.130
06/03/73	0.770	2.100	0.080	0.029	0.200
07/12/73	0.273	2.000	0.680	0.740	0.960
08/05/73	0.760	2.900	0.990	1.300	1.650
09/18/73	1.700	3.150	0.176	1.060	1.250
Maximum	1.700	3.800	2.000	1.300	1.650
Minimum	.031	.760	0.065	0.029	0.085
Mean	.451	2.086	0.514	0.354	0.527

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon (1974).

A definite pollution source is shown by these data for the phosphate contribution to the Little Minnesota River.

Sulfates (SO_4): No state standards apply for sulfate concentrations. However, the sulfate content of the Little Minnesota River is high and comparable with the lower Whetstone River water.

Iron (Fe): South Dakota has a standard for iron which is not to exceed 0.2 mg/liter. This value is exceeded in the Little Minnesota River (Table 42) and is probably a result of the geology of the watershed rather than from man's activities.

Fecal coliforms: Data on fecal coliform counts from the sampling station near Peever, South Dakota, show very acceptable counts in compliance with South Dakota standards. Only one count (Table 42) exceeded the standard of 1,000/100 ml. Unfortunately, no bacteriological data are available at Brown's Valley, Minnesota, to show the quality of water there with reference to that parameter.

(3) Minnesota tributaries to Big Stone Lake--data analyses: Big Stone Lake tributaries from the Minnesota side of the watershed traverse land areas populated with farmstead and livestock operations as does the South Dakota portion of the watershed. Wastes from livestock feed lots in Minnesota have been shown to contribute pollutants to streams which enter Big Stone Lake.113/

Available data on water quality for this portion of the watershed are shown in Tables 45-49. The only bacteriological data (Table 45) are from a 1967 report. The more recent data were from the 1972-73 study by the Eutrophication Survey Branch of EPA (Tables 46-49).

Minnesota water quality standards for the unnamed creeks are covered in Appendix H under "General Standards Applicable to All Intrastate Waters of the State (WPC 15)."

TABLE 45

REPORT ON DISPOSAL OF WASTES FROM LIVESTOCK FEEDING
IN THE BIG STONE LAKE WATERSHED
APRIL 12-14, 1967

Analytical and Flow Data

Station	Source of Sample and Location of Sampling Point
1	Drainage course below Lewis Haanen livestock yard at head of ravine
2	County Ditch 7 (Fish Creek) at CAR 51
3	Unnamed creek at State Highway 7 (Section 35, Foster Township)
4	Unnamed creek immediately above David Lindholm cattle yard just east of County Road 7 about 1/2 mile north of State Highway 7
5	Unnamed creek about 100 yards downstream from State Highway 7 and about 1/2 mile west of County Road 7. (Below David Lindholm cattle yards)

Station	1	2	3	4	5
Laboratory Number	7568	7569	7570	7571	7572
Date Collected	4-14-67	4-14-67	4-14-67	4-14-67	4-14-67
Time Collected	8:00 a.m.	8:30 a.m.	9:00 a.m.	9:15 a.m.	9:30 a.m.
Total Coliform Group Organisms (MPN/100 ml)	35,000	220	2,400	2,800	170,000
Fecal Coliforms (MPN/100 ml)	2,400	<20	790	<20	110,000
Total Solids	2,400	560	400	240	1,700
Total Volatile Matter	760	140	235	59	490
Suspended Solids	610	15	8	12	170
Suspended Volatile Matter	150	6	4	4	42
5-Day Biochemical Oxygen Demand	28	2.3	1.0	0.8	140
Phosphorus	3.1	0.26	0.10	0.23	4.7
Nitrites	0.56	0.03	0.03	0.04	<0.02
Nitrates	0.48	0.48	0.30	0.60	0.28
Kjeldahl Nitrogen	19	1.3	0.77	1.4	24
Estimated Flow (gpm)	60	2,700	1,800	30	60

a/ Results are in milligrams per liter except as noted.
< means less than.
Source: Report on disposal of wastes from livestock feedlots in the Minnesota Watershed of Big Stone Lake, Minnesota Pollution Control Agency, 1967.

TABLE 46

WATER QUALITY DATA FOR UNNAMED CREEK--
6.5 MILE NW OF ORTONVILLE, MINNESOTA, STATION 2707 D1

Date	$NO_2 + NO_3$, Total as N (mg/ℓ)	Kjeldahl Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Orthophosphate as P (mg/ℓ)	Total Phosphate as P (mg/ℓ)
10/14/72	0.086	0.550	0.092	0.029	0.105
11/19/72	0.053	0.330	0.115	0.025	0.056
12/16/72	0.080	0.540	0.240	0.017	0.050
01/13/73	0.088	0.540	0.240	0.014	0.070
02/10/73	0.052	0.330	0.132	0.016	0.045
03/18/73	3.300	1.470	0.245	0.042	0.140
04/02/73	0.200	1.100	0.060	0.022	0.067
04/15/73	0.015	0.520	0.026	0.026	0.065
05/01/73	0.017	0.700	0.016	0.035	0.080
05/19/73	<0.010	0.480	0.073	0.027	0.075
06/03/73	0.610	0.750	0.063	0.028	0.085
07/12/73	0.018	2.200	0.470	0.044	0.125
08/05/73	0.018	1.050	0.042	0.063	0.[illegible]
09/18/73	0.022	1.100	0.056	0.046	0.115
Maximum	3.300	2.200	0.470	0.063	0.170
Minimum	0.015	0.330	0.016	0.014	0.045
Mean	0.351	0.833	0.134	0.031	0.089

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon (1974).

TABLE 47

WATER QUALITY DATA FOR UNNAMED CREEK--8 MILES
NW OF ORTONVILLE, MINNESOTA, STATION 2709E1

Date	$NO_2 + NO_3$, Total as N (mg/ℓ)	Kjeldahl Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Orthophosphate as P (mg/ℓ)	Total Phosphate as P (mg/ℓ)
10/14/72	1.390	0.550	0.060	0.044	0.085
11/19/72	2.500	0.360	0.040	0.016	0.043
12/16/72	3.900	0.340	0.082	0.027	0.036
10/13/73	3.900	0.160	0.100	0.022	0.040
02/10/73	3.650	0.480	0.042	0.019	0.035
03/18/73	2.500	0.500	0.105	0.021	0.050
04/02/73	2.600	0.750	0.030	0.030	0.055
04/15/73	0.026	0.900	0.058	0.020	0.035
05/01/73	1.900	0.400	0.046	0.022	0.040
05/19/73	2.600	0.600	0.051	0.020	0.045
06/03/73	1.260	1.320	0.315	0.069	0.085
07/12/73	3.000	0.700	0.120	0.039	0.070
08/05/73	2.900	0.650	0.037	0.031	0.055
09/18/73	3.000	0.[illegible]55	0.028	0.038	0.055
Maximum	3.900	1.320	0.315	0.069	0.085
Minimum	0.026	0.160	0.028	0.016	0.035
Mean	2.509	0.597	0.080	0.030	0.052

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon (1974).

TABLE 48

WATER QUALITY DATA FOR UNNAMED CREEK--
13 MILES NW OF ORTONVILLE, MINNESOTA, STATION 2709F1

Date	$NO_2 + NO_3$, Total as N (mg/ℓ)	Kjeldahl Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Orthophosphate as P (mg/ℓ)	Total Phosphate as P (mg/ℓ)
10/14/72	0.034	0.450	0.070	0.035	0.060
11/19/72	0.154	0.720	0.069	<0.005	0.022
12/16/72	0.273	0.330	0.120	0.027	0.036
01/13/73	0.252	0.420	0.138	<0.005	0.015
02/10/73	0.270	0.220	0.088	0.011	0.015
03/18/73	0.680	0.720	0.115	0.020	0.055
04/02/73	0.029	0.380	0.035	0.016	0.030
04/15/73	2.600	1.890	0.067	0.030	0.110
05/01/73	0.075	1.980	0.520	0.168	0.300
05/19/73	0.023	0.370	0.033	0.026	0.050
06/03/73	0.378	2.260	0.063	0.011	0.070
07/12/73	0.086	3.150	0.210	0.068	0.123
08/05/73	0.094	0.760	0.075	0.030	0.067
Maximum	2.600	3.150	0.520	0.168	0.300
Minimum	0.023	0.220	0.033	0.011	0.015
Mean	0.381	1.050	0.123	0.034	0.073

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon (1974).

TABLE 49

WATER QUALITY DATA FOR FISH CREEK--
3.0 MILE SOUTH OF BEARDSLEY, MINNESOTA, STATION 2709G1

Date	$NO_2 + NO_3$, Total as N (mg/ℓ)	Kjeldahl Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Orthophosphate as P (mg/ℓ)	Total Phosphate as P (mg/ℓ)
10/14/72	0.120	1.700	0.078	0.063	0.138
11/19/72	0.760	0.320	0.078	0.031	0.094
12/16/72	0.700	0.560	0.185	0.064	0.132
01/13/73	0.600	1.300	0.190	0.084	0.140
02/10/73	0.810	0.580	0.168	0.031	0.080
03/18/73	1.320	2.800	0.290	0.154	0.270
04/02/73	0.350	1.540	0.071	0.032	0.080
04/15/73	0.150	1.100	0.052	0.042	0.105
05/01/73	0.330	0.780	0.034	0.066	0.130
05/19/73	0.046	0.910	0.072	0.200	0.300
06/03/73	0.770	1.200	0.147	0.021	0.280
07/12/73	0.120	1.260	0.280	0.070	0.110
08/05/73	0.058	0.790	0.048	0.320	0.390
09/18/73	0.098	2.100	0.310	0.085	0.175
Maximum	0.810	2.800	0.310	0.320	0.390
Minimum	0.046	0.320	0.034	0.021	0.080
Mean	0.440	1.203	0.143	0.090	0.173

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon (1974).

A summary of those standards shows the following limiting concentrations or ranges:

Substance or Characteristic	Limiting Concentration or Range*
BOD_5	25 mg/liter
Fecal coliforms	200 (MPN)/100 ml
Total suspended solids	30 mg/liter
Pathogenic organisms	None
Oil	Essentially free of visible oil
Phosphorus (P)**	1.0 mg/liter
Turbidity	25 JTU
pH range	6.5-8.5
Unspecified toxic or corrosive substances	None at levels acutely toxic to humans or animals or plant life, or directly damaging to real property.

Minnesota standards for Fish Creek are the same as those for the Little Minnesota River and are covered in Table 35.

Sampling station locations for the EPA study (Tables 46-49) are shown in Figure 7.

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* The arithmetic mean for concentrations of 5-day biochemical oxygen demand and total suspended solids shall not exceed the stated values in a period of 30 consecutive days and 45 mg/liter in a period of 7 consecutive days. Disinfection of waste-water effluents to reduce the coliform organism levels is required year round. The geometric mean for the fecal coliform organisms shall not exceed the stated value in a period of 30 consecutive days and 400 most probable number/100 ml in a period of 7 consecutive days. The application of the coliform and pathogenic organism standards ordinarily shall be limited to sewage or other effluents containing admixtures of sewage and shall not apply to industrial wastes except where the presence of sewage, fecal coliform organisms or viable pathogenic organisms in such wastes is known or reasonably certain.

** Where the discharge of effluent is directly to or affects a lake or reservoir. Removal of nutrients from all wastes shall be provided to the fullest practicable extent wherever sources of nutrients are considered to be actually or potentially detrimental to preservation or enhancement of the designated water uses.

(a) Minnesota Pollution Control Agency study: Data from the 1967 study (Table 45) assessed under the present Minnesota standards are as follows:

Fecal coliforms: Sampling Stations 1, 3, and 5 are above the allowable standards of 200/100 ml.

Total solids: Values for sampling Stations 1 and 5 are extremely high although no standards cover this parameter.

Total volatile matter: This parameter relates the amount of organic combustible matter to total solids. The ratio of organic to total solids is about 1:4 for all stations except Station 3 which is about 1:2. Evidence of pollutable material is indicated.

Suspended solids: Standards give a maximum mean level of 30 mg/liter over a 30-day period or 45 mg/liter over a 7-day sampling period. Stations 1 and 5 show values far in excess of maximum allowable concentrations.

BOD_5: Standards show a maximum mean value of 25 mg/liter over a 30-day period or 45 mg/liter over a 7-day period. Station 5 is extremely high and indicates an untreated sewage effluent type condition.

Phosphorus (P): Standards show a maximum value of 1.0 mg/liter. Stations 1 and 5 have values 3.1 and 4.7 times the maximum allowable concentration.

Nitrites: This intermediate stage of ammonia breakdown is extremely high at Station 1.

Nitrates: Nitrates are not excessive but are highest at Stations 1, 2, and 4. Nitrate values show only a part of the total nitrogen concentration and should be assessed in that respect.

Kjeldahl nitrogen: This parameter shows the nitrogen concentration of both ammonia and organic nitrogen as (N). Excessively high values are shown at Stations 1 and 5.

(b) Eutrophication Survey Branch study: The study by the Eutrophication Survey Branch of EPA was directed toward analysis of water samples for nitrogen and phosphate concentrations (those major nutrients responsive to aquatic plant growth including algae). The location of applicable sampling stations is shown in Figure 12 (see p. 140). Data from Tables 46-49 are assessed with respect to the present Minnesota

water quality standards. The only parameter listed for the unnamed streams (Tables 46-48) which has an applicable standard is total phosphate, with a maximum concentration of 1.0 mg/liter.

The only parameter listed for Fish Creek (Table 49) applicable to the standards is ammonia with a maximum concentration of 1.5 mg/liter.

Total phosphate (P): None of the total phosphate analyses (Tables 46-48) are above the Minnesota standards under the classification for these streams. However, most all values for total phosphorus, including Table 49, exceed the recommended level of 0.050 mg/liter[2/] where streams enter a lake.

Orthophosphate (P): Orthophosphate is the most soluble portion of the total phosphate concentration. Because the ratio of orthophosphate to total phosphate is about 1:2 to 1:4, indications would suggest that wash-water from farmsteads or other residences along the streams is entering the creeks.

Ammonia nitrogen (N): None of the samples from the Fish Creek station exceed the maximum allowable concentration of 1.5 mg/liter.

Nitrogen to phosphate ratio: For natural waters the N to P ratio is roughly 10:1.[2/] Fish Creek data, figuring the nitrate, nitrite, and Kjeldahl analysis as total nitrogen, show N to P ratios to be in the acceptable range for a natural water.

The nitrogen to phosphate ratio for the unnamed creek (Table 46) is roughly 10:1. N to P ratio for unnamed creeks (Tables 47 and 48) ranges from 20:1 to 40:1.

Comparing like parameters from the 1967 report (Table 45) to those of the 1972-73 report (Tables 46-49) no total phosphate concentrations were found in the latter report which approached those found at Stations 1 and 5 of the former report (3.1 and 4.7 mg/liter). The same observation holds for Kjeldahl nitrogen at the same Stations 1 and 5 where the 1967 report showed 19 and 24 mg/liter nitrogen as N.

Data from Fish Creek in the two reports (Tables 45, Station 2 and Table 49) are comparable for total nitrates and phosphates.

(4) Big Stone Lake: The waters of Big Stone Lake are classified as interstate waters and both South Dakota and Minnesota have standards for those waters. Applicable standards for each state are shown in Table 35. Also see Appendices G and H.

Water quality data (Tables 50-53 and Figures 8-14) presented for Big Stone Lake were obtained from EPA Storet Retrieval (1958-74); Dorand Engineering Services, Brookings, South Dakota (1971-74); and the Eutrophication Survey Branch of EPA at Corvallis, Oregon (1972). The sampling station for the Dorand Engineering study is shown in Figure 6 and stations for the Eutrophication Survey Branch study are shown in Figure 7. The latter study by the Eutrophication Survey Branch was done primarily to determine nitrogen and phosphate concentrations in the lake as those major nutrients contribute to the growth of aquatic plants, including algae.

(a) Storet retrieval data: Parameters for assessing water quality from this source are presented in Tables 50 and 51 and selected parameters are evaluated. Parameters in Table 50 are those covered either by both states' standards or by one of the state's standards (Table 35), and data are given in a chronological progression. Table 51 presents the nitrogen and phosphate water quality parameters in a chronological progression.

Data from Table 50 were assessed for the following parameters:

Dissolved oxygen: During the years 1958-1961, 1969, 1971, and 1973, dissolved oxygen concentrations were below the states' standards of 5.0 mg/liter. This appears to be a reoccurring situation at this sampling station on the lake.

Temperature: In general, temperatures fall below the maximum standards. One sampling (6-17-70) exceeds the South Dakota standards of 80°F.

Ammonia nitrogen: Maximum standards are 1.0 mg/liter ammonia as N. Data on this parameter are available since 1961. Standards were exceeded in 1965, 1968, 1969, and 1971. An extreme value of 9.500 mg/liter was reported in 1968.

Chromium: Minnesota standards give a maximum of 0.05 mg/liter. The two analyses data reported are less than 20 mg/liter or 0.020 mg/liter. Chromium does not appear to be a contaminant in this watershed.

TABLE 50

WATER QUALITY DATA FOR BIG STONE LAKE AT ORTONVILLE, MINNESOTA--
PARAMETERS COVERED BY MINNESOTA AND SOUTH DAKOTA STANDARDS

Date	DO (mg/ℓ)	Temperature (°F)	Ammonia as N (mg/ℓ)	Chromium as Cr (μg/ℓ)	Copper as Cu (μg/ℓ)	Cyanides as CN (mg/ℓ)	Oil (mg/ℓ)	pH (units)	Phenols (mg/ℓ)	Turbidity (JTU)	H_2S (mg/ℓ)	Iron as Fe (mg/ℓ)	Suspended Solids (mg/ℓ)	Fecal Coliforms (Count/100 ml)
05/19/58	7.6	62.0						8.2		36.0				
07/08/58	3.9	62.0						8.2		27.0				
08/04/58		77.0						6.7		15.0				
09/09/58		70.0						6.8		4.0				
10/14/58		59.0						6.8		10.0				
11/14/58	11.0	37.0						8.4		15.0				
01/06/59	0.1	32.0						7.0		25.0				
10/19/59		50.0						7.6		28.0				
11/30/59		33.0						7.6		20.0				
02/03/60	0.9	34.0						6.6		35.0			23	
09/06/60	7.3	83.0						7.4		12.0			34	
11/16/60	0.2	37.0						7.7		19.0			26	
03/14/61	5.9	37.0	0.400					8.0		9.0			12	
06/27/61	2.2	78.0	0.280					7.4		20.0			32	
11/07/61	11.9	36.0	0.060					7.7		14.0			21	
04/03/62	7.5	32.0						7.5		40.0			96	
08/07/62	6.1	79.0						8.0		17.0			32	
10/01/62	5.6	58.0	0.400					8.0		19.0			42	
12/11/62	12.6	32.0	0.060					8.0		12.0			34	
04/23/63	13.4	46.0	0.040					8.6		20.0			34	
12/03/63	13.0	36.0	<0.050					7.8		15.0			14	<200
04/24/64	7.6	48.0	<0.050					8.5		54.0			71	3300
06/18/64	6.7	76.0	0.160					7.5		20.0			46	<200
07/16/64	9.3	79.0	0.080					7.3		13.0			19	<200
08/20/64	5.4	73.0	0.060					7.5		18.0			42	<200
11/05/64	8.2	47.0	0.060					8.1		22.0			26	<200
03/19/65	5.7	33.0	1.100					7.8		10.0			12	200
06/14/65	7.0	67.0	0.190					7.4		12.0			20	< 20
07/30/65	8.8	78.0	<0.050					7.5		15.0			25	200
07/12/67		68.0	0.050		160			8.5		20.0			28	20
08/30/67		70.0	0.190	<20	50	<0.050		7.7		30.0			28	20
10/25/67		45.0	0.160					8.0		85.0		2.40	110	< 20
01/17/68		43.0	0.050		100			8.4		12.0		0.22	12	< 20
03/06/68		41.0	9.500					7.8		15.0		0.40	12	20
04/24/68		43.0	0.070		90			8.0		54.0		1.50	78	3300
06/19/68		74.0	0.190		80			8.1		13.0		0.19	19	< 20
07/18/68		80.0	<0.050		40			8.1		12.0		0.21	9	< 20
08/14/68		69.0	0.070		50			8.4		19.0			27	20
09/18/68		67.0	0.780		80			8.0		70.0			50	< 20
10/09/68		57.0	0.400		10			7.9		140.0			94	310

TABLE 50 (Continued)

Date	DO (mg/ℓ)	Temperature (°F)	Ammonia as N (mg/ℓ)	Chromium as Cr (μg/ℓ)	Copper as Cu (μg/ℓ)	Cyanides as C (mg/ℓ)	Oil (mg/ℓ)	pH (units)	Phenols (mg/ℓ)	Turbidity (JTU)	H_2S (mg/ℓ)	Iron as Fe (mg/ℓ)	Suspended Solids (mg/ℓ)	Fecal Coliforms (Count/100 ml)
11/06/68		44.0	0.590		10			8.1		66.0		0.80	57	< 20
12/04/68		35.0	0.510		20			8.0		4.1		0.09	6	< 20
01/27/69	7.7	35.0	1.400		<10			7.6		4.1		1.20	5	< 20
02/05/69	5.6	40.0	0.730		<10			7.5		3.7		0.12	6	< 20
04/02/69	3.0	40.0	1.000		20			7.5		7.0		0.35	20	< 20
04/29/69	9.8	53.0	0.630		<10			7.6		16.0		0.35	16	20
06/12/69	8.7	64.0	0.140		<10			8.2		23.0		0.59	49	< 20
07/09/69	10.6	72.0	0.410		<10			8.1		10.0		1.50	26	80
08/06/69	5.6	77.0	0.310		<10			7.5		5.7		<0.02	15	20
09/10/69	8.9	63.0	0.180		<10			8.5		9.4		0.08	13	< 20
10/09/69	9.9	55.0	0.140	<20	30	<0.050	0.7	8.7		20.0	<0.10	0.99	38	70
10/30/69	9.9	41.0	0.310		<10			8.2		8.7		0.18	9	20
12/04/69	15.3	36.0	0.130		<10			8.3		5.3		0.09	13	50
01/08/70	8.8	32.0	0.700		<10			7.7		0.5		0.25	16	20
02/04/70	8.1	34.0	0.850		<10			7.7		3.5		0.09	6	< 20
04/13/70	6.6	52.0	0.200		<10			8.1		3.3		0.09	8	< 20
06/17/70	12.4	82.0	0.070		<10			8.2		11.0		0.23	27	80
07/22/70	8.3	79.0	0.120		<10			8.0		8.3		0.22	23	< 20
08/19/70	8.4	76.0	0.130		<10			8.5		6.4		0.11	18	< 20
09/16/70	10.4	56.0	0.070		10			8.6		17.0		0.52	37	20
10/15/70	10.3	51.0	0.210		16			8.2		28.0		1.20	79	< 20
10/29/70	10.1	50.0	0.200		26			8.2		17.0		0.55	47	20
12/01/70	12.2	34.0	0.200		<10			8.3		6.3		0.30	16	< 20
01/05/71	10.1	36.0	0.200		16			7.6		4.8		0.54	9	< 20
02/18/71	8.5	40.0	0.290		<10			7.6		3.9		0.14	7	20
03/11/71	1.2	40.0	1.500		<10			7.2		9.0		0.56	14	20
04/07/71	13.4	42.0	0.230		<10			7.5		4.7		0.15	12	< 20
06/09/71	8.5	70.0	0.310		<10			8.3		15.0		1.50	41	270
07/14/71	10.4	74.0	0.160		<10			8.4		22.0			34	80
08/11/71	6.5	73.0	0.333		<10			8.0		23.0			51	490
09/03/71	7.4	73.0	0.160		11			7.9		12.0		0.74	22	< 20
10/14/71	10.1	57.0	0.130		31			7.8		15.0			45	20
11/05/71	12.1	38.0	0.200		<10			8.0		33.0		3.60	180	3300
04/14/72	11.4	40.0	0.650		13			7.6		170.0			310	4900
06/01/72	9.7	70.0	0.270		11			8.0		5.4		0.25	11	< 20
06/28/72	10.3	71.0	0.100		<10			7.9		15.0		1.30	36	230
07/28/72	7.2	70.0	0.150		26			7.4		130.0		7.50	390	1700
08/25/72	8.2	71.0	0.180		<10			8.2		8.4		0.43	19	110
09/28/72	10.3	51.0	<0.050		<10			7.9		22.0		0.69	41	< 20
10/26/72	10.8	42.0	0.180		<10			7.8		8.4		0.40	18	50
11/22/72	14.5	33.0	0.160		<10			7.4		3.8		0.33	5	80
12/28/72	9.8	36.0	0.750		<10			7.9		3.9		0.25	5	80

TABLE 50 (Concluded)

Date	DO (mg/ℓ)	Temperature (°F)	Ammonia as N (mg/ℓ)	Chromium as Cr (µg/ℓ)	Copper as Cu (µg/ℓ)	Cyanides as C (mg/ℓ)	Oil (mg/ℓ)	pH (units)	Phenols (mg/ℓ)	Turbidity (JTU)	H_2S (mg/ℓ)	Iron as Fe (mg/ℓ)	Suspended Solids (mg/ℓ)	Fecal Coliforms (Count/100 ml)
01/11/73	7.0	32.0	0.840		<10			7.4		3.3		0.12	6	< 20
02/20/73	3.0	42.0	0.970		<10			7.8		5.4		0.89	12	< 20
03/21/73	9.0	46.0	0.660		<10			7.2		6.2		0.35	11	< 20
04/20/73	9.4	56.0	<0.050		<10			8.1		12.0		0.64	33	< 20
06/29/73	9.9	71.0	<0.050		<10			8.1		21.0		0.95	38	20
07/27/73	6.6	73.0	0.050		<10			8.0		30.0		1.50	73	4900
09/19/73	8.9	65.0	0.070		<10			8.4		18.0		1.70	37	80
10/23/73	10.4	62.0	0.210		25			8.0		11.0		7.30	27	170
12/17/73	12.1	32.0	0.560		<10			8.0		3.5		0.59	6	80
01/10/74	11.2	36.0	0.470		<10			7.8		2.5		0.23	3	80

Source: Environmental Protection Agency, Storet Data (1974).

TABLE 51

NITROGEN AND PHOSPHATE CONCENTRATIONS FOR BIG STONE LAKE AT ORTONVILLE, MINNESOTA
(Lat. 45° 18' 08" Long. 96° 27' 02")

Date	Organic Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Nitrate Nitrogen as N (mg/ℓ)	Phosphate Total as P (mg/ℓ)
5/19/58	--	--	<0.100	0.180
10/14/58	--	--	0.200	0.700
11/14/58	--	--	0.200	0.560
1/6/59	--	--	<0.100	3.600
10/19/59	--	--	0.060	1.500
11/30/59	--	--	<0.100	1.400
3/14/61	--	0.400	--	--
6/27/61	--	0.280	--	--
11/7/61	--	0.060	--	--
4/3/62	--	--	--	0.300
8/7/62	--	--	--	0.180
10/1/62	--	0.400	--	0.280
12/11/62	--	0.060	--	0.130
4/22/63	--	0.040	--	0.320
12/3/63	--	<0.050	--	0.340
4/24/64	--	<0.050	--	0.360
6/18/64	--	0.160	--	0.120
7/16/64	--	0.080	--	0.320
8/20/64	--	0.060	--	0.300
11/5/64	--	0.060	--	0.250
3/19/65	--	1.100	--	0.630
6/14/65	--	0.190	--	0.150
7/30/65	--	<0.050	--	0.110
7/12/67	1.500	0.050	0.600	0.140
8/30/67	1.200	0.190	0.280	0.220
10/25/67	2.200	0.160	0.540	0.300
1/17/68	1.800	<0.050	0.080	0.230
3/6/68	2.900	9.500	0.160	0.150
4/24/68	1.400	0.070	0.150	0.270
6/19/68	1.000	0.190	0.270	0.090
7/18/68	1.100	<0.050	<0.020	0.080
8/14/68	0.200	0.070	0.050	<0.010
9/18/68	1.800	0.780	0.110	0.250
10/9/68	0.700	0.400	0.050	0.370
11/6/68	1.500	0.590	0.070	0.200
12/4/68	0.850	0.510	0.170	0.150
1/27/69	0.540	1.400	0.780	0.180
2/5/69	1.500	0.730	0.390	0.200
4/2/69	1.400	1.000	0.190	0.300
4/29/69	0.830	0.630	0.480	0.220

TABLE 51 (continued)

Date	Organic Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Nitrate Nitrogen as N (mg/ℓ)	Phosphate Total as P (mg/ℓ)
6/12/69	1.400	0.140	0.110	0.180
7/9/69	0.920	0.410	0.140	0.170
8/6/69	1.300	0.310	0.170	0.200
9/10/69	1.400	0.180	0.150	0.210
10/9/69	1.700	0.140	0.190	0.240
10/30/69	1.200	0.310	0.140	0.190
12/4/69	1.500	0.130	0.150	0.170
1/8/70	1.300	0.700	0.160	0.200
2/4/70	0.920	0.850	0.130	0.200
4/13/70	1.000	0.200	<0.050	0.160
6/17/70	1.500	0.070	<0.030	0.270
7/22/70	1.700	0.130	0.280	0.240
8/19/70	1.500	0.130	<0.050	0.200
9/16/70	1.500	0.070	0.130	0.190
10/15/70	1.700	0.210	<0.100	0.230
10/29/70	1.400	0.200	0.370	0.140
12/1/70	1.100	0.200	<0.100	0.080
1/5/71	1.200	0.200	0.120	0.110
2/18/71	0.980	0.290	0.060	0.060
3/11/71	2.500	1.500	0.060	1.000
4/7/71	1.800	0.230	<0.050	0.310
6/9/71	1.600	0.310	0.090	0.200
7/14/71	--	0.160	0.300	0.390
8/11/71	--	0.330	0.280	0.270
9/3/71	--	0.160	0.400	0.220
10/14/71	--	0.130	<0.050	0.610
11/5/71	--	0.200	0.200	0.530
4/14/72	--	0.650	0.100	1.100
6/1/72	--	0.270	0.170	0.160
6/28/72	--	0.100	<0.050	0.240
7/28/72	0.940	0.150	0.400	0.600
8/25/72	--	0.180	0.170	0.320
9/28/72	--	<0.050	0.060	0.240
10/26/72	--	0.180	0.270	0.150
11/22/72	--	0.160	0.450	0.230
12/28/72	--	0.750	0.580	0.390
1/11/73	--	0.840	0.260	0.320
2/20/73	--	0.970	0.090	0.140
3/21/73	--	0.660	0.390	0.160
4/20/73	--	<0.050	<0.050	0.170
6/29/73	--	<0.050	<0.050	0.230
7/27/73	--	0.050	0.270	0.250

TABLE 51 (Concluded)

Date	Organic Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Nitrate Nitrogen as N (mg/ℓ)	Phosphate Total as P (mg/ℓ)
9/19/73	1.400	0.070	0.790	0.310
10/23/73	1.500	0.210	0.170	0.170
12/17/73	1.200	0.560	0.440	0.150
1/10/74	1.400	0.470	0.310	0.250

Sources: Minnesota Pollution Control Agency, Storet Data, 2/5/74.
Environmental Protection Agency, Storet Data, 6/14/74.

TABLE 52

WATER QUALITY DATA FROM BIG STONE LAKE SAMPLING STATION BSL-1 - MONTHLY PROGRESSION

Station		Temperature (°F)	pH (units)	Conductivity (μmhos/cm)	Total Hardness as $CaCO_3$ (mg/ℓ)	Calcium Hardness as $CaCO_3$ (mg/ℓ)	Total Alkalinity as $CaCO_3$ (mg/ℓ)	Chlorides as Cl^- (mg/ℓ)	Sulfates as $SO_4^=$ (mg/ℓ)	Total Phosphorus as P (mg/ℓ)	Nitrate Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)
(BSL-1)	11-30-71	32	8.1	940	440	250	168	12	335	0.05	0.1	0.25
	12-29-71	32	8.2	1,070	500	240	183	15	420	0.05	0.2	0.21
	2-1-72	32	8.1	1,200	520	320	216	17	420	0.13	0.1	0.30
	3-2-72	32	7.7	1,210	540	320	226	16	400	0.05	0.3	0.06
	4-3-72	35	7.4	520	210	140	100	7	120	0.27	0.2	1.10
	5-15-72	59	8.1	831	380	240	160	11	230	0.03	0.0	0.31
	6-14-72	71	8.3	885	380	220	174	8	258	0.20	0.1	0.35
	7-17-72	70	8.3	888	390	220	172	11	260	0.20	0.0	0.19
	8-9-72	69	8.2	915	380	200	176	10	230	0.32	0.0	0.17
	9-12-72	64	8.9	905	320	200	134	11	270	0.10	0.0	0.14
	10-17-72	39	8.6	890	340	180	128	9	280	0.12	0.0	0.25
	11-14-72	30	8.4	920	350	220	140	5	285	0.08	0.1	0.42
	12-18-72	34	8.1	1,110	430	260	168	14	300	0.03	0.1	0.53
	1-16-73	34	7.8	1,150	440	210	178	15	350	0.05	2.0	0.04
	2-19-73	36	7.7	1,160	500	230	198	16	342	0.02	0.0	0.47
	3-21-73	44	8.3	760	290	170	128	5	144	0.18	0.2	0.56
	4-24-73	48	8.4	970	420	210	154	8	305	0.14	0.0	0.21
	5-21-73	67	8.3	1,000	400	210	166	13	290	0.08	0.0	0.26
	6-18-73	75	8.7	980	400	210	172	11	318	0.16	0.0	0.56
	7-16-73	78	8.6	930	350	1[illegible]0	148	14	306	0.17	0.0	0.34
	8-13-73	77	7.9	910	390	220	160	9	270	0.13	0.1	0.64
	9-1--73	70	8.1	975	380	220	160	13	322	0.20	0.0	0.34
	10-8-73	63	7.9	1,121	390	250	144	14	374	0.01	1.1	0.25
	11-5-73	37	7.8	1,061	440	247	158	15	270	0.02	0.1	0.23
	12-5-73	33	8.0	1,075	490	240	170	8	364	0.12	0.1	0.14
	1-21-74	35	7.9	1,308	639	390	205	11	438	0.23	0.0	0.29
	2-25-74	36	7.7	1,345	621	318	213	6	524	0.10	0.0	0.28
	3-25-74	40	8.1	1,184	535	285	186	9	446	0.20	0.1	0.13

TABLE 52 (Concluded)

Station	Kjeldahl Nitrogen as N (mg/ℓ)	Total Residue (mg/ℓ)	Total Suspended Matter (mg/ℓ)	DO (mg/ℓ)	BOD (mg/ℓ)	Turbidity (% Trans.)	Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Sodium as Na (mg/ℓ)
(BSL-1) 11-30-71	1.1	697	5	12.7	1	12.5	<5	<3	--
12-29-71	1.6	787	0	12.4	2	8.0	0	0	--
2-1-72	1.6	905	12	16.7	3	2.8	<5	<3	--
3-2-72	1.6	934	8	10.0	3	2.8	23	0	--
4-3-72	1.9	370	22	18.7	<9	4.3	<5	<3	--
5-15-72	1.1	651	8	9.1	2	4.0	500	<3	--
6-14-72	1.2	687	18	7.3	3	11.0	400	<3	--
7-17-72	1.1	666	7	7.8	4	8.0	20	<3	--
8-9-72	2.7	694	14	10.1	22	9.0	<5	<3	--
9-12-72	1.1	650	22	11.4	8	10.0	<5	<3	--
10-17-72	1.5	685	32	11.4	8	13.0	100	<3	--
11-14-72	1.7	554	15	13.3	8	10.5	4	<3	--
12-18-72	1.3	752	1	9.4	4	5.9	<5	<3	--
1-16-73	1.0	798	3	6.4	2	5.8	<5	<3	42
2-19-73	1.9	837	1	7.1	2	0.6	--	--	51
3-21-73	2.1	451	15	14.5	13	2.8	15	6	25
4-24-73	1.4	672	20	10.9	6	6.0	<5	<3	47
5-21-73	1.3	751	9	9.1	3	16.0	15	13	49
6-18-73	1.9	739	13	11.6	9	11.0	75	<3	49
7-16-73	3.0	726	20	9.5	11	11.0	25	<3	55
8-13-73	2.1	811	16	5.0	4	8.0	280	40	60
9-10-73	1.5	825	16	8.1	4	6.0	200	10	61
10-8-73	2.1	855	29	8.5	4	4.0	35	3	51
11-5-73	1.6	851	9	11.1	4	4.0	16	3	54
12-5-73	1.3	906	12	13.3	2	2.0	<5	<3	57
1-21-74	1.8	1,048	10	12.4	2	1.0	<5	<3	52
2-25-74	1.5	1,094	4	10.4	2	0.5	<5	<3	51
3-25-74	1.4	966	4	11.4	4	2.0	5	<3	48

Source: Water Monitoring Program for Otter Tail Power Company, Dorand Engineering Services, Brookings, South Dakota, 1971-74.

TABLE 53

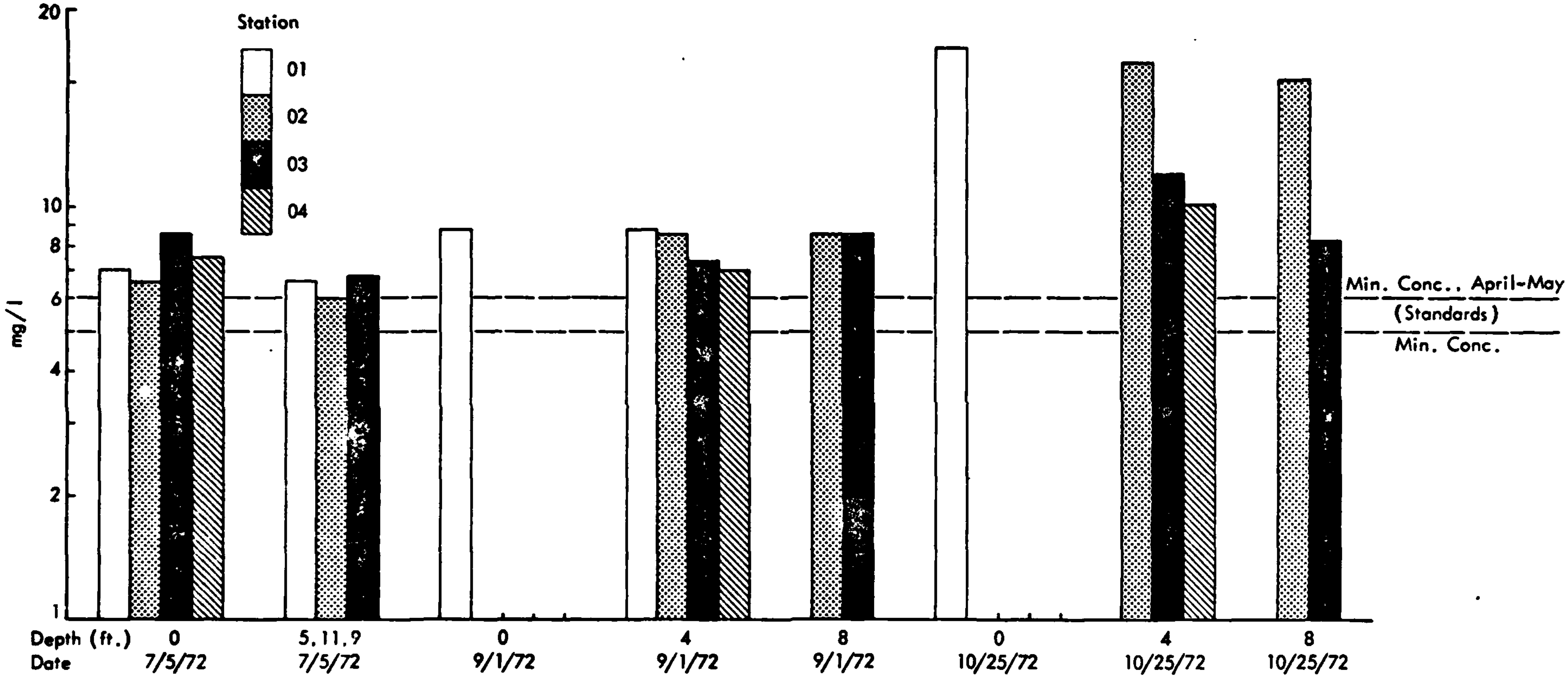
WATER QUALITY FOR BIG STONE LAKE--
NATIONAL EUTROPHICATION SURVEY, 1972

Station Number	Date	Sample Depth (ft)	Water Temperature (°C)	DO (mg/ℓ)	Transparency Secchi (in.)	Turbidity % Transmission	Conductivity (μmhos/cm)	PH (units)
270901	7/5/72	0	22.0	7.1	23	-	770	7.9
270902	7/5/72	0	21.5	6.6	106	-	730	7.9
270903	7/5/72	0	21.5	8.7	45	-	800	8.20
270904	7/5/72	0	20.0	7.6	21	-	870	8.10
270901	7/5/72	5	21.5	6.6	-	-	740	7.9
270902	7/5/72	11	21.5	6.0	-	-	750	7.8
270903	7/5/72	9	21.5	6.8	-	-	800	8.10
270901	9/1/72	0	19.3	8.8	47	-	810	8.5
270902	9/1/72	0	-	-	46	-	800	8.55
270903	9/1/72	0	-	-	53	-	840	8.35
270904	9/1/72	0	19.4	-	14	-	930	7.97
270901	9/1/72	4	19.3	8.8	-	79.5	850	8.5
270902	9/1/72	4	20.2	8.6	-	82.1	800	8.55
270903	9/1/72	4	20.4	7.4	-	82.3	850	8.31
270904	9/1/72	4	19.4	7.0	-	-	940	7.97
270902	9/1/72	8	20.2	8.6	-	83.0	800	8.60
270903	9/1/72	8	20.3	8.6	-	82.5	825	8.40
270901	10/25/72	0	5.2	12.4	31	77.0	800	8.5
270902	10/25/72	0	-	-	31	-	800	8.60
270903	10/25/72	0	-	-	31	-	820	8.70
270904	10/25/72	0	-	-	30	-	980	8.10
270902	10/25/72	4	5.9	12.2	-	78.0	800	8.70
270903	10/25/72	4	5.7	11.2	-	81.0	800	8.70
270904	10/25/72	4	4.8	10.0	-	78	950	8.10
270902	10/25/72	8	5.9	12.0	-	78.0	800	8.70
270903	10/25/72	8	5.8	8.2	-	78.0	850	8.50

TABLE 53 (Concluded)

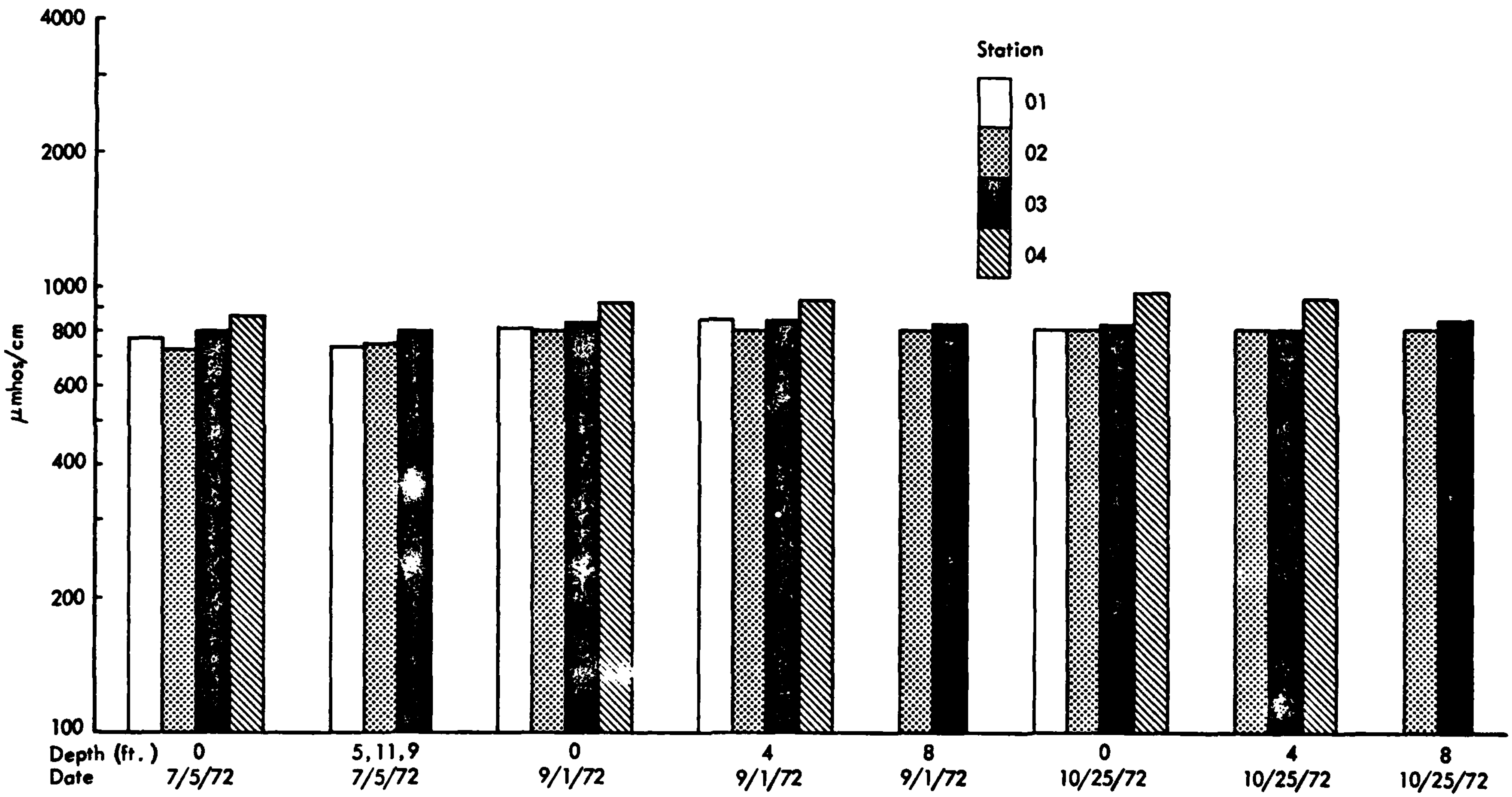
Station Number	Date	Alkalinity Total as $CaCo_3$ (mg/ℓ)	NO_2NO_3, Total as N (mg/ℓ)	Ammonia, Total as N (mg/ℓ)	Phosphate, Total as P (mg/ℓ)	Phosphate, Dissolved as P (mg/ℓ)	Chlorophyll A (μg/ℓ)
270901	7/5/72	165	0.06	0.30	0.131	0.108	-
270902	7/5/72	164	0.07	0.26	0.139	0.128	-
270903	7/5/72	179	0.08	0.08	0.098	0.072	2.4
270904	7/5/72	181	0.06	0.11	0.153	0.081	-
270901	7/5/72	164	0.08	0.30	0.270	0.099	-
270902	7/5/72	164	0.06	0.25	0.143	0.125	-
270903	7/5/72	176	0.14	0.27	0.127	0.100	-
270901	9/1/72	161	0.13	0.25	0.166	0.162	7.9
270902	9/1/72	158	0.15	0.16	0.166	0.162	6.8
270903	9/1/72	150	0.15	0.64	0.203	0.185	7.3
270904	9/1/72	193	0.34	0.76	0.339	0.302	12.4
270901	9/1/72	168	0.13	0.28	0.171	0.142	-
270902	9/1/72	158	0.15	0.18	0.171	0.142	-
270903	9/1/72	152	0.14	0.66	0.224	0.179	-
270904	9/1/72	192	0.36	0.78	0.360	0.294	-
270902	9/1/72	127	0.08	0.18	0.168	0.140	
270903	9/1/72	131	0.16	0.64	0.217	0.174	
270901	10/25/72	124	0.06	0.11	0.118	0.047	54.0
270902	10/25/72	127	0.08	0.17	0.079	0.044	52.0
270903	10/25/72	131	0.09	0.18	0.062	0.038	43.8
270904	10/25/72	194	0.26	0.25	0.241	0.223	2.8
270902	10/25/72	126	0.09	0.16	0.098	0.066	-
270903	10/25/72	131	0.10	0.18	0.103	0.063	-
270904	10/25/72	196	0.27	0.26	0.250	0.225	-
270902	10/25/72	126	0.08	0.16	0.125	0.056	-
270903	10/25/72	141	0.13	0.21	0.122	0.066	-

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon, June, 1974.



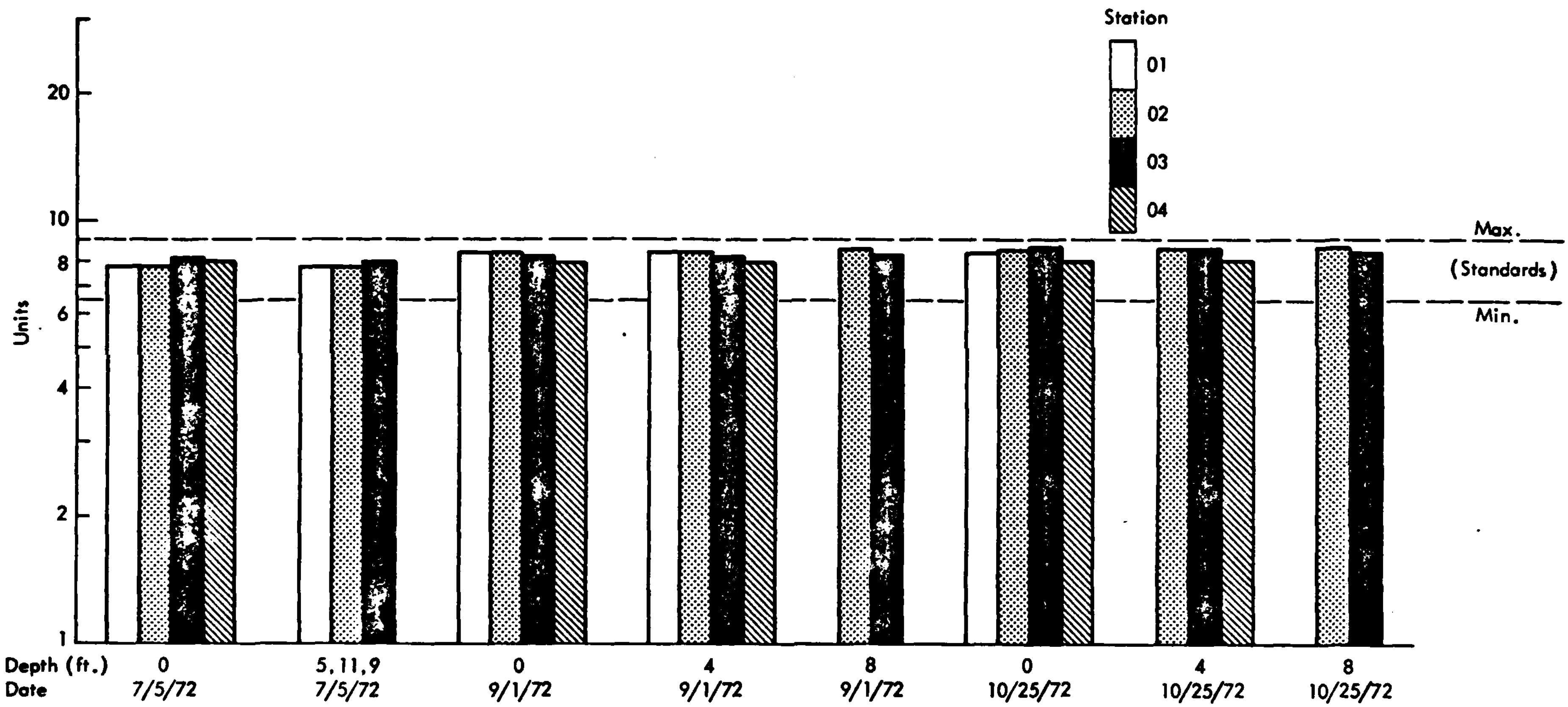
Source: Environmental Protection Agency, Eutrophication Branch, Corvallis, Oregon 6/4/74

Figure 8 - Dissolved Oxygen - Four Stations on Big Stone Lake Taken at Various Depths on Corresponding Dates



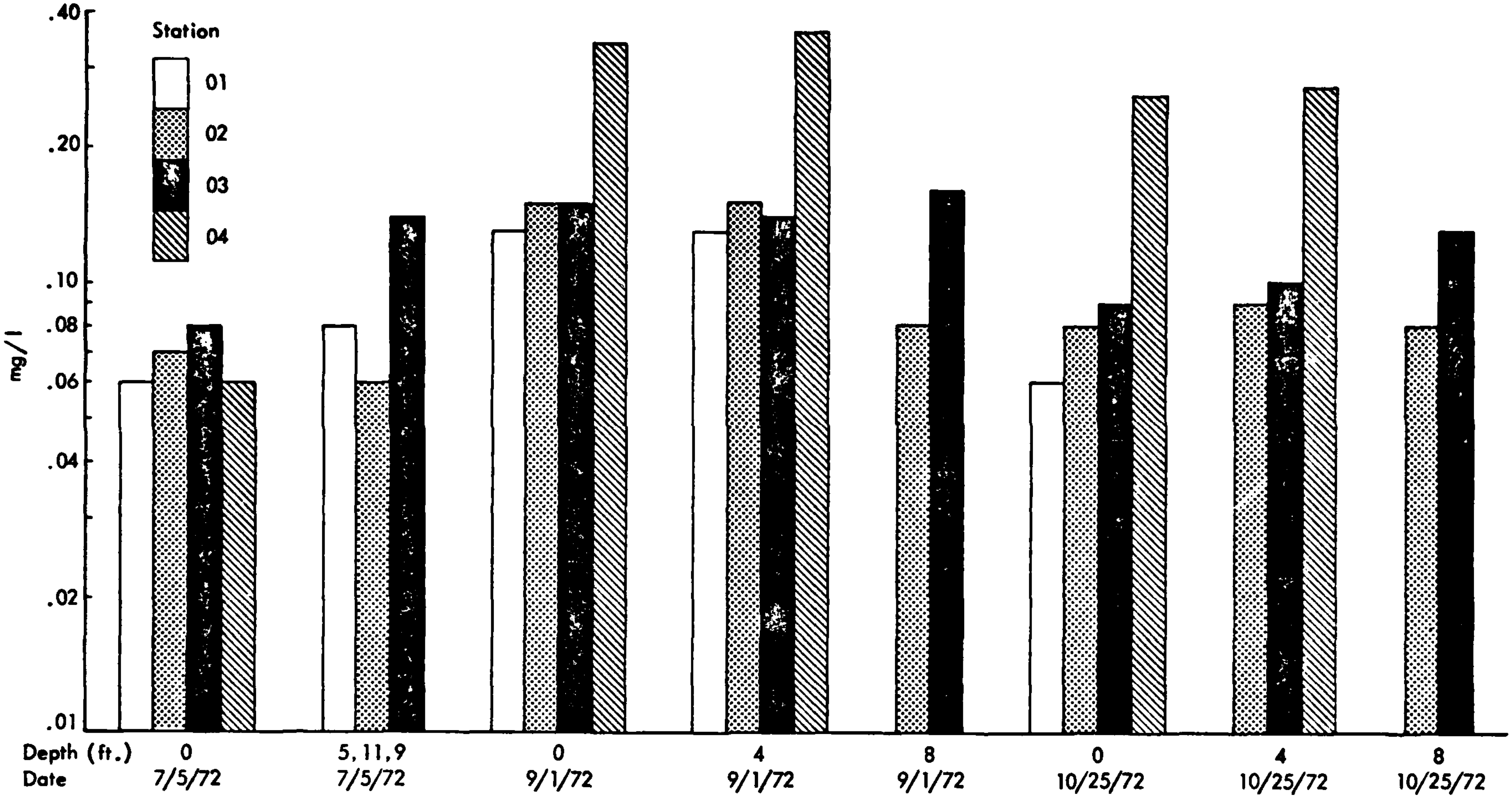
Source: Environmental Protection Agency, Eutrophication Branch, Corvallis, Oregon 6/4/74

Figure 9 - Conductivity - Four Stations on Big Stone Lake Taken at Various Depths on Corresponding Dates



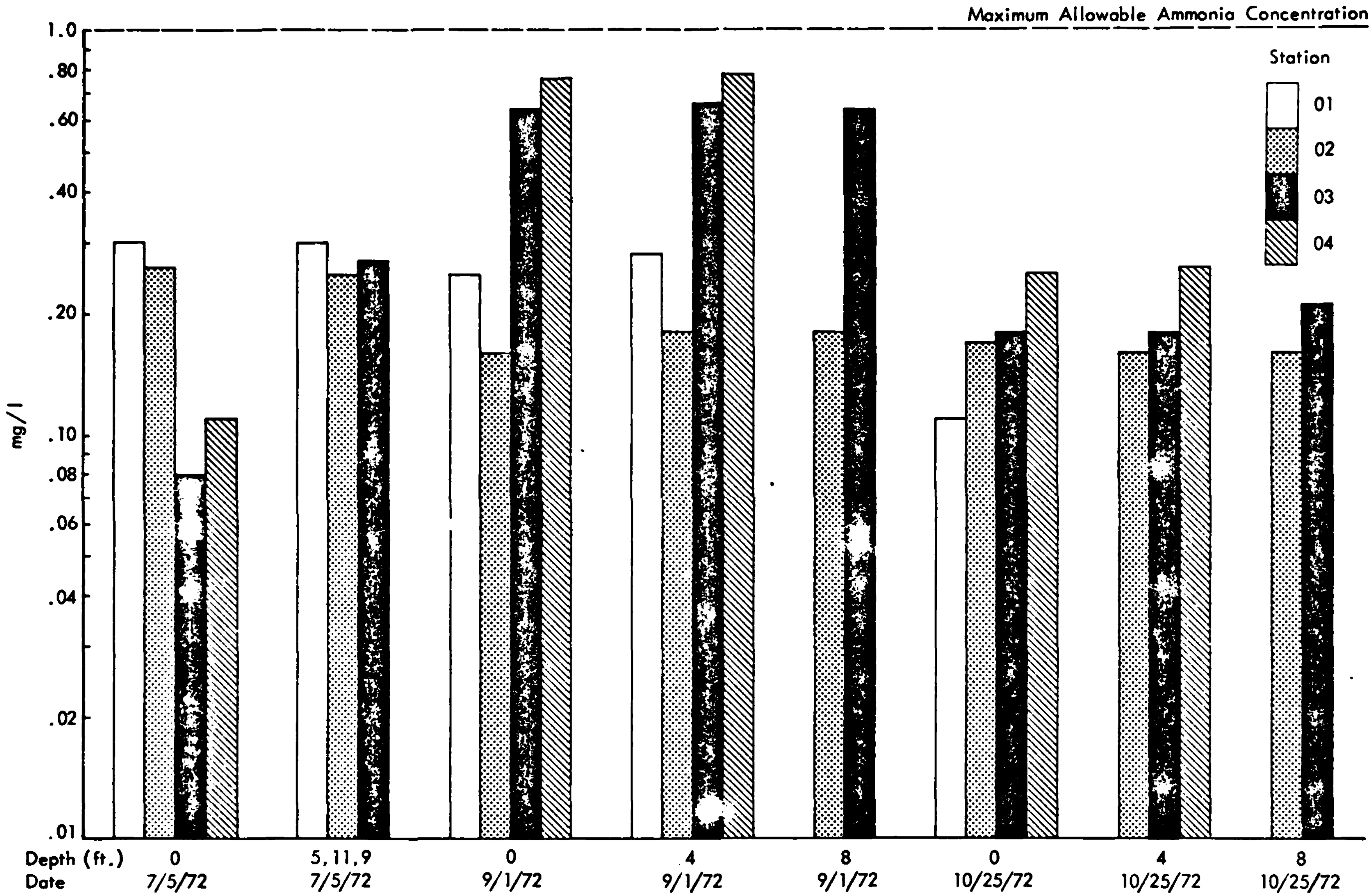
Source: Environmental Protection Agency, Eutrophication Branch, Corvallis, Oregon 6-4-74.

Figure 10 - pH - Four Stations on Big Stone Lake Taken at Various Depths on Corresponding Dates



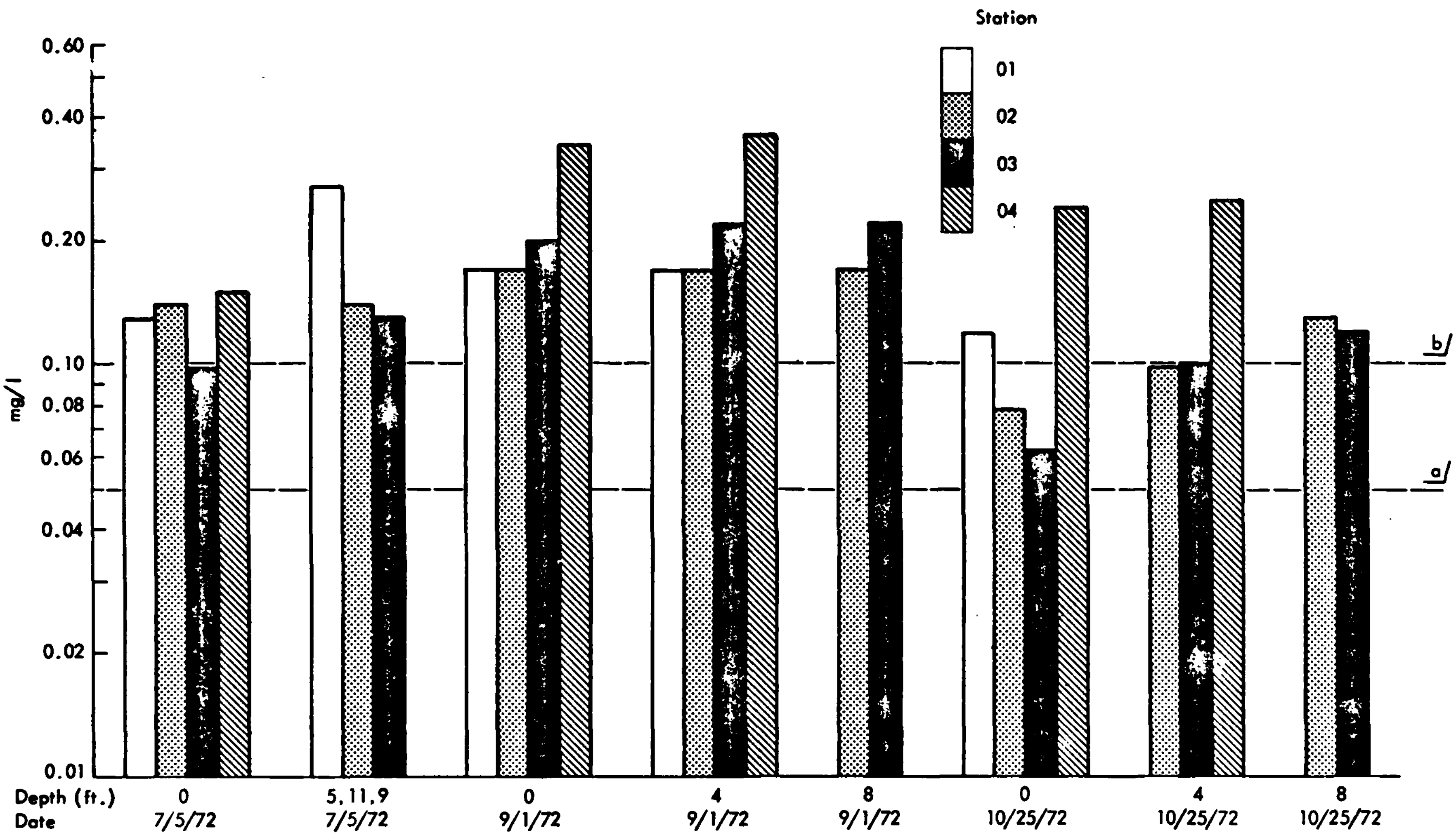
Source: Environmental Protection Agency, Eutrophication Branch, Corvallis, Oregon 6/4/74

Figure 11 - $NO_2 + NO_3$; Total as N - Four Stations on Big Stone Lake Taken at Various Depths on Corresponding Dates



Source: Environmental Protection Agency, Eutrophication Branch,
Corvallis, Oregon 6/4/74

Figure 12 - Ammonia, Total as N - Four Stations on Big Stone Lake Taken at Various Depths on Corresponding Dates



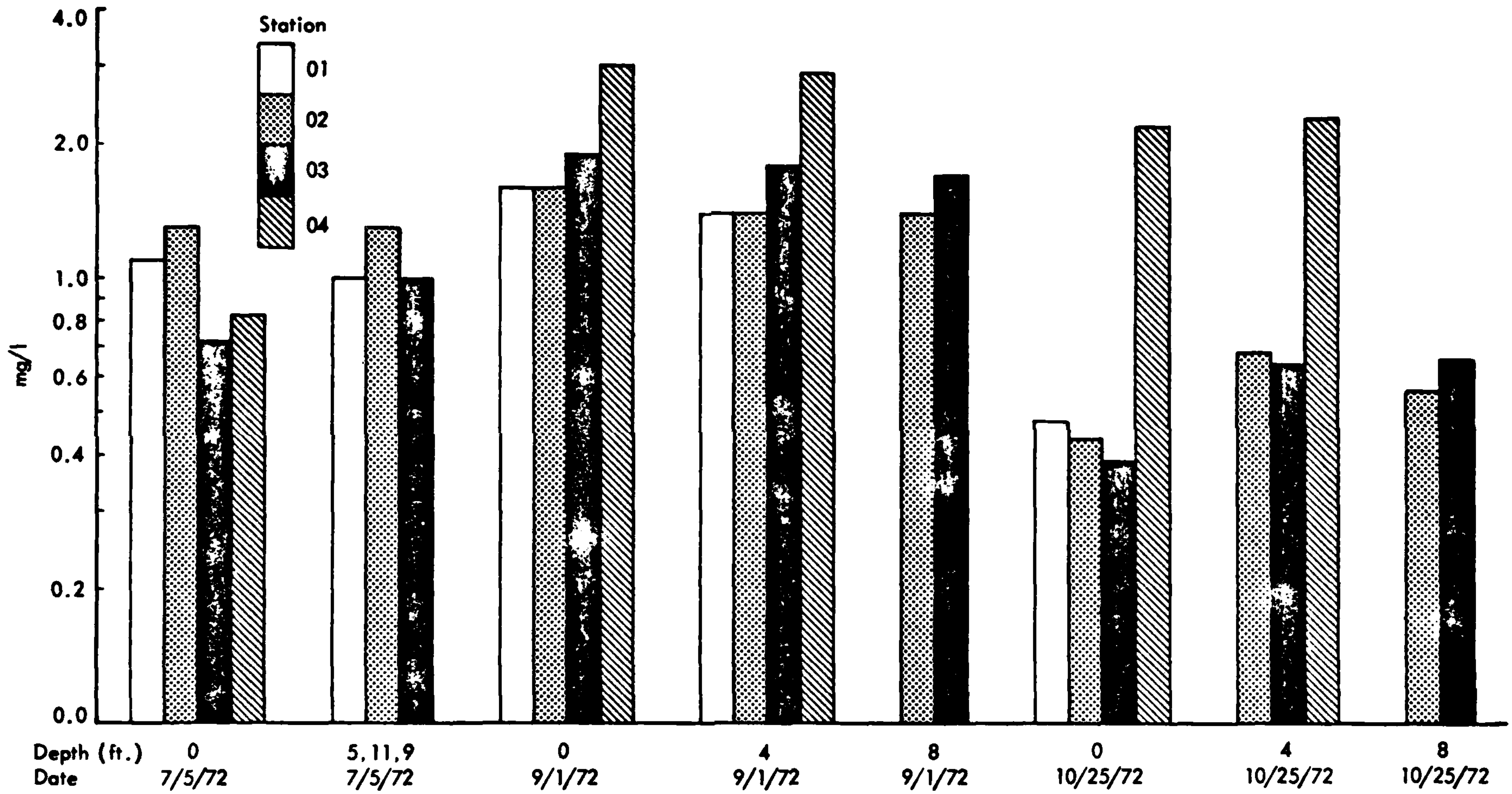
Source: Environmental Protection Agency, Eutrophication Branch, Corvallis, Oregon 6-4-74

LEGEND:

a/ Federal recommendation for lakes

b/ Federal recommendation for streams

Figure 13 - Phosphate, Total as P - Four Stations on Big Stone Lake Taken at Various Depths on Corresponding Dates



Source: Environmental Protection Agency, Eutrophication Branch,
Corvallis, Oregon 6/4/74

Figure 14 - Phosphate, Dissolved as P - Four Stations on Big Stone Lake Taken at Various Depths on Corresponding Dates

Copper: Minnesota standards give a maximum concentration of 0.01 mg/liter. During 1967-68, values reported are far in excess of the maximum. Concentrations have exceeded the standard at least once in each of the following years, 1969-73.

Cyanides: Maximum standards by both states for this parameter is 0.02 mg/liter. The two analyses made show values less than 0.050 mg/liter. Apparently the methodology used in analysis had a lower limit of sensitivity of 0.050 mg/liter. Cyanides do not appear to be a pollutant for the watershed.

Oil: The standard is 0.5 mg/liter for Minnesota and 10.0 mg/liter for any petroleum products for South Dakota. Only one analysis is shown (10-9-69) and that result 0.7 is above the standard.

pH: pH values are all within the standards of 6.5-9.0.

Phenols: Although Minnesota has a maximum concentration standard of 0.010 mg/liter, no data are available from Storet Data.

Turbidity: Minnesota standards have a maximum of 25 JTU and South Dakota 50 JTU. Values in 1968, 1971, and 1972 exceed 100 JTU. The turbidity at this sampling station is directly affected by the Whetstone River and surface runoff contributes to this problem of turbidity in the lower part of the lake.

Hydrogen sulfide: South Dakota standards give a maximum concentration of undissociated H_2S as 0.002 mg/liter. Only one analysis was performed during the 16 years of reported sampling. The value reported is less than 0.10 mg/liter. Apparently the standard if five-fold less than the limiting concentration for the method used.

Iron: South Dakota standards give a maximum concentration of 0.200 mg/liter. Sample data from 1967-73 show concentrations that exceed the standard more than 50% of the time. Apparently the geology of the area is such that the standard will be difficult to meet.

Suspended solids: South Dakota standards show a maximum value of 90 mg/liter for this parameter. In general, the data show compliance with the standard. However, in 1971 and 1972 peak concentrations were due to surface runoff carried to the lake by the Whetstone River.

Fecal coliforms: Both states have a standard of 200/100 ml for the fecal coliform count. During excessive surface runoff this standard is exceeded and may be associated with animal feedlots along the Whetstone River.

Nitrogen and phosphorus: Data for the following parameters (nitrogen and phosphorus) are shown in Table 51. The total nitrogen concentrations cannot be assessed from 1958-67 as certain parameters were not evaluated. A like situation exists for the period 7-14-71 to 7-19-73.

Organic nitrogen: Increases in the organic nitrogen concentration may be an index of sewage, industrial, or feedlot wastes in surface waters.[40] The data presented indicate that the normal organic nitrogen concentration is between 1.200 and about 1.500 mg/liter. Three peaks occur in the data (1967, 1968, and 1971) with values between 2.200-2.900 mg/liter. An excessive concentration of organic nitrogen is present for aquatic productivity in the lake.

Ammonia nitrogen: This parameter was assessed from the same data in Table 50. Ample concentrations of ammonia nitrogen are available for aquatic productivity of the lake.

Nitrate nitrogen: Nitrates are a final form of nitrogen in biological oxidation and in nitrogen fixation by certain bacteria. Data show a wide variation in concentration in the lake water (0.020-0.790 mg/liter as N). A median range appears to be between 0.100-0.200 mg/liter. Ample concentrations of nit.ate nitrogen are available for aquatic productivity of the lake.

Total nitrogen: The sum of the organic nitrogen, ammonia nitrogen, nitrite and nitrate nitrogen is considered as total nitrogen. As the nitrite nitrogen concentrations are usually small the total nitrogen will be assumed to represent the other three components. The total nitrogen concentration at any point in time appears to provide an excessive amount for aquatic productivity.

Phosphorus, total (P): Phosphorus concentrations near to or in excess of 0.050 mg/liter are conducive to algal blooms and aquatic plant growth in nitrogen, other minor and trace elements, sunlight, and optimum temperature conditions are present.

This major element for aquatic plant growth, including algae is generally 2-70 times the 0.050 mg/liter recommended for lakes by the National Technical Advisory Committee.[2]

(b) Dorand Engineering Services Survey data (Table 52)

Water temperature °F: Monthly samples (1971-74) are all below the 80°F maximum limit for South Dakota standards.

pH: Values for the monthly samplings are all within the pH range of standards, 6.5-9.0.

Conductivity: Values range from 760-1,345 μmhos/cm which indicates a high concentration of soluble inorganic ions.

Total hardness: The water is hard ranging from 210-639 mg/liter as $CaCO_3$. A recommended value of 500 mg/liter as $CaCO_3$[2/] is a maximum recommended level for drinking water.

Total alkalinity: The total alkalinity which is mostly bicarbonate alkalinity ranges from about 128-226 mg/liter as $CaCO_3$. Productive waterfowl habitats should have a bicarbonate alkalinity of between 30-130.[2/] Values for the lake water in this study exceed recommended levels.

Sulfates: Concentrations of sulfates (120-524 mg/liter as SO_4) are high as compared to many Minnesota waters. As the sulfate concentrations exceed the carbonate concentrations, water is considered alkaline.[1/]

Phosphorus, total: Total phosphorus values range from 0.01-0.27 mg/liter as P. The maximum value is over four times the recommended level for lakes or reservoirs.[2/]

Nitrate nitrogen: Two values during the study are high 1.1 and 2.0 mg/liter as N. A more meaningful interpretation should include Kjeldahl nitrogen, nitrate, and nitrite nitrogen which are considered as the total nitrogen contribution.

Ammonia nitrogen: Ammonia nitrogen is derived from the first oxidative step in degrading organic material. Standards for South Dakota and Minnesota call for a maximum value of 1.0 mg/liter as N. Values obtained in this study are below the maximum limit except one which was 1.10 mg/liter.

Kjeldahl nitrogen: The Kjeldahl analysis includes both organic and ammonia nitrogen. Values reported in the study range from 1.0-3.0 mg/liter as N. The values indicate a rather constant load of organic material in the lake water.

Total nitrogen: Although not shown in the table, the sum of Kjeldahl nitrogen and nitrate nitrogen is the approximate total nitrogen. In two instances this value is slightly above 3.0 mg/liter as N, but in general the values are between 1.5 and 2.0 mg/liter. This element is in ample supply for aquatic plant growth.

Total residue: The total solids concentration of these waters is high, although no state standards apply to this parameter. A limit of 500 mg/liter total residue is desirable for drinking water.[110] Total solids for lake water are generally 500-1,000 mg/liter.

Total suspended matter: This parameter is also synonymous with nonfilterable residue. South Dakota standards give a maximum of 90 mg/liter. No samples from this study exceeded those standards.

Dissolved oxygen (DO): Concentrations of DO reported in this study exceed minimum state standards of 5.0 mg/liter. Two exceptionally high values are reported (16.7 and 18.7 mg/liter). The maximum solubility of oxygen in water at 0°C is 14.6 mg/liter.[110]

BOD: Values reported are in a very acceptable range. Only three monthly samples in over 2 years sampling exceeded 10 mg/liter. A maximum allowable value for sewage effluent is 25 mg/liter.

Turbidity: Turbidity values are very low ranging from 0.5-16.0% transmission based upon 100% for distilled water. Sampling from the lake bank probably accounted for such turbid water.

Coliforms, total: All counts reported are below the 1,000/100 ml standard.

Fecal coliforms: All counts reported are below the states' standards of 200/100 ml sample.

(c) Eutrophication Survey Branch, EPA, study, Table 53 and Figures 8-14: Big Stone Lake samples were taken three times during 1972 (7-5, 9-1, and 10-25-72). Both surface and subsurface water samples were taken at those sampling periods (Table 53).

Water temperature: Analyses for the three sampling periods show temperatures to be all below the maximum South Dakota standard of 80°F (26.3°C).

Dissolved oxygen: Standards for both states for the sampling periods recorded are 5.0 mg/liter DO (Table 35). All samples are above the standards shown in the graphical presentation in Figure 8.

Transparency (Secchi disc): The Secchi disc method for transparency is a more qualitative measurement than the method by light transmission. The painted disc is lowered in water to the point where it is no longer visible and that reading is taken in inches below the water surface. Measurements taken are shown to be between 14 and 106 in.--extremely turbid to very clear. Most measurements indicate a moderately turbid condition.

Turbidity, percent transmission: Based upon the turbidity of distilled water at 100% for light transmission, values reported range from 78-83% light transmission. Moderate turbidity is indicated which is due to soluble and suspended matter which scatters light.

Conductivity: Conductivity measurements range from 740-980 µmhos/cm. Measurements indicate high concentrations of soluble inorganic compounds. A graphical presentation for this parameter is shown in Figure 9.

pH: States' standards show pH ranges between 6.5-9.0 (Table 35). All values are in an acceptable range and are shown graphically in Figure 10.

Alkalinity ($CaCO_3$): Total alkalinity measurements range from 124-196 mg/liter as $CaCO_3$. The lake waters are known to be hard waters and contain both the calcium and magnesium which form carbonates and bicarbonates. Bicarbonate salts predominate in these waters.

Nitrite and nitrate nitrogen (N): The nitrite-nitrate nitrogen values reported range from 0.06-0.36 mg/liter as N. These samples, taken from a midpoint in lake width, should be unaffected by shoreline point source pollution and should be representative of the body of water at the particular sampling period. This source of nitrogen is reasonably low. Higher values (Figure 11) are apparent on both 9-1-72 and 10-25-72 for Station 4 (the upper part of the lake below Brown's Valley, Minnesota) at both the surface and the 4-ft depth.

Ammonia nitrogen (N): Ammonia is sometimes considered as an index to organic pollution because ammonia is a first stage microbial degradation product of organic material. Both states have

standards which are not to exceed 1.0 mg/liter of ammonia nitrogen. None of the values reported exceed the standards. A graphical presentation of data is shown in Figure 12. On 9-1-72 the highest values are apparent at Station 3 at the surface, 4-ft, and 8-ft depths and at Station 4 at the surface and the 4-ft depth. Station 4 is at the upper end of the lake below Brown's Valley, Minnesota, and Station 3 is located about midpoint of the length of the lake about 13 miles northwest of Ortonville, Minnesota (Figure 7).

Phosphate, total (P): No standards for phosphate apply for Big Stone Lake for either South Dakota or Minnesota. The federal recommendation for streams, however, is a maximum of 0.10 mg/liter and 0.050 mg/liter for lakes, reservoirs, or streams entering them.

A graphical presentation for this parameter is shown in Figure 13 where all samples exceed the 0.05 mg/liter level and about 80% of the samples exceed the 0.10 mg/liter level. Total phosphate concentrations ranged from 0.062-0.360 mg/liter.

Orthophosphate (P): Orthophosphates constitute the most soluble and available form of the total phosphates. Values ranged from 0.056-0.302 mg/liter.

About 88% of the samples exceed a 0.050 mg/liter concentration. Highest values approaching 0.300 mg/liter are apparent (Figure 13) for Station 4 at the surface and the 4-ft depth. High values approaching 0.200 mg/liter are apparent for Station 3 at the surface, 4-ft, and 8-ft depths.

Chlorophyll A: Phytoplankton is difficult to separate from other filterable material. One method of quantitating the productivity of surface waters for relative amounts of algal bloom is to extract the chlorophyll from phytoplankton and analyze for this constituent. Although it is difficult to relate the chlorophyll analysis to a definite phytoplankton crop, high values such as those shown in Table 53 for 10-25-72 show a heavy algal bloom for Stations 1-3.

(d) Summary of surface water quality for the Big Stone Lake Watershed: Data presented for surface water quality show that both the Little Minnesota and Whetstone rivers carry surface waters in the range of 500 mg/liter measured as $CaCO_3$. Both rivers have waters high in sulfates, show high alkalinity measurements, and both, consequently, have very high specific conductance values (in the range of 1,200 µmhos/cm). Both waters are considered alkaline as pH values are normally between 7.5-8.0.

The Whetstone River data (Table 40) show a mean value of 37.3 tons/day for dissolved solids and 18.05 tons/day for suspended solids.

Both rivers carry excessive total phosphate concentrations. The Whetstone River total phosphate concentrations are normally 0.200-0.300 mg/liter (Tables 36 and 37) and the Little Minnesota River concentrations below the Brown's Valley, Minnesota, sewage treatment plant are in a mean range of 0.500 mg/liter (Table 54).

Both rivers normally carry ammonia nitrogen concentrations of from 0.200 mg/liter for the Whetstone (Tables 36 and 37) to 0.500 mg/liter for the Little Minnesota (Table 54). Kjeldahl nitrogen for the Whetstone River normally is in the range of 1.00 mg/liter (Tables 36 and 37) and the concentration for the Little Minnesota River is in the range of 2.000 mg/liter (Table 54).

Tributary streams to Big Stone Lake from the Minnesota portion of the watershed may be expected to provide a mean range of nutrients (as shown in Table 54).

Parameter	Mean Range (mg/liter)
Nitrates and nitrites (N)	0.300-2.500
Kjeldahl nitrogen (N)	0.600-1.200
Ammonia nitrogen (N)	0.080-1.400
Orthophosphate (P)	0.030-0.090
Phosphate, total (P)	0.050-0.170

Fecal coliform counts for the Whetstone River and for streams from the Minnesota portion of the watershed may be expected to exceed 200/100 ml during winter runoff or during periods of heavy precipitation. Animal husbandry activities including confined feeding of livestock contribute to excessive concentrations of fecal microorganisms in surface waters.

Waters of Big Stone Lake are greatly influenced by the surface waters entering it. Most of the chemical and physical parameter values summarized for the tributaries to the lake are similar to the lake itself.

Water sampling done by EPA in 1972 includes analyses data for four points on the lake located in Figure 7. Those samples analyzed are considered characteristic of the lake waters during the summer and fall seasons and unaffected by shoreline disturbances.

TABLE 54

WATER QUALITY DATA FOR TRIBUTARIES TO BIG STONE LAKE
(EPA Eutrophication Survey, 10/14/72-9/18/73)

Location	No. Samples		Nitrates and Nitrites as N (mg/ℓ)	Total Kjeldahl Nitrogen as N (mg/ℓ)	Ammonia Nitrogen as N (mg/ℓ)	Orthophosphate as P (mg/ℓ)	Total Phosphate as P (mg/ℓ)	Total Nitrogen as N[a] (mg/ℓ)
Stat. 2709D1	14	Max.	3.300	2.200	0.470	0.063	0.170	
Unnamed Stream		Min.	0.015	0.330	0.016	0.014	0.050	
St. Hwy. 7, 6.5 mi.		Mean	0.351	0.833	0.133	0.031	0.089	1.184
N.W. of Ortonville, Minn.								
Stat. 2709E1	14	Max.	3.900	1.320	0.315	0.069	0.085	
Unnamed Stream		Min.	0.026	0.160	0.030	0.016	0.035	
St. Hwy. 7, 8.0 mi.		Mean	2.509	0.597	0.079	0.030	0.052	3.107
N.W. of Ortonville, Minn.								
Stat. 2709F1	14	Max.	2.600	3.150	0.520	0.168	0.300	
Unnamed Stream		Min.	0.023	0.220	0.033	0.005	0.015	
St. Hwy. 7, 13.0 mi.		Mean	0.353	0.975	0.114	0.034	0.069	1.328
N.W. of Ortonville, Minn.								
Sta. 2709G1	14	Max.	13.200	2.800	0.290	0.320	0.390	
Fish Creek		Min.	0.046	0.320	0.034	0.021	0.080	
Co. Hwy. 51, 3.0 mi.		Mean	1.519	1.210	0.143	0.090	0.173	2.729
S. of Beardsley, Minn.								
Stat. 2709C1	14	Max.	12.600	3.300	0.330	1.470	3.200	
S. Fork of Whetstone River		Min.	0.011	0.880	0.013	0.007	0.080	
at Milbank, South Dakota		Mean	2.100	1.828	0.111	0.192	0.466	3.928
Station 2709A1	14	Max.	0.610	2.100	0.880	0.160	0.232	
L. Minn. R at		Min.	0.014	0.560	0.008	0.007	0.027	
Brown's Valley		Mean	0.203	1.280	0.208	0.051	0.097	1.483
Above STP								
Station 2709A2	14	Max.	1.700	3.800	2.000	1.300	1.650	
L. Minn. R at		Min.	0.031	0.760	0.065	0.029	0.085	
Brown's Valley		Mean	0.451	2.086	0.514	0.354	0.527	2.537
Below STP								

Source: Environmental Protection Agency, Eutrophication Survey Branch, Corvallis, Oregon, June 4, 1974.

a/ Sum of nitrates, nitrites, and Kjeldahl nitrogen unweighted mean values.

A summary of EPA sampling analyses data and a corresponding approximate value for tributaries for the same parameter are shown in Table 55. These data show a close relationship for DO between the lake and tributaries.

Specific conductance values for the lake are lower than for tributaries; approximately, 800 vs 1,200 µmhos/cm (Table 55). Also values for the upper portion of the lake (Stations 270904 and 270903) are higher than the lower portion of the lake.

pH values for the lake are comparable to those for the tributaries.

Total alkalinity as $CaCO_3$ is lower for the lake than for tributaries; approximately 150 vs 290 mg/liter. Values for the lake are higher for the extreme upper portion of the lake (Station 270904).

Nitrite-nitrate nitrogen values are much lower in the lake than in tributaries; approximately, 0.100 vs 0.300-2.500 mg/liter. The upper portion of the lake (Station 270904) has higher NO_2 and NO_3 values as (N) than for the rest of the lake.

Ammonia nitrogen is somewhat lower in the lake than tributaries; approximately, 0.100-0.300 vs 0.080-1.400 mg/liter. The upper portion of the lake (Stations 270904 and 270903) have higher values than the lower portion.

Total phosphate values for the lake are somewhat higher than those for the tributaries; approximately, 0.100-0.200 vs 0.050-0.170 mg/liter. The upper portion of the lake (Station 270904) shows values about 30% higher than those for the lower portion.

3. Ground Water

a. Supply: Part of the water from rain, melting snow, wetlands, lakes, and streams in the Big Stone Watershed seeps into the ground. Some of this water is retained in the soil near the surface as soil moisture. The remainder continues to seep downward until it reaches the level where water has filled up (saturated) the open space between soil or rock particles. The upper surface of this saturated zone (the water table) and the underground water immediately below it moves by gravity flow from areas of higher to areas of lower elevation. Although the position of the water table is largely controlled by the topography of the land surface, the boundary of the ground water drainage area does not always coincide exactly with the surface water drainage area.

TABLE 55

WATER QUALITY FOR BIG STONE LAKE - SUMMARY 1972

Sampling Station		DO (mg/ℓ)	Conductivity (μmhos/cm)	pH (units)	Alkalinity as CaCO3 (mg/ℓ)	$NO_2 + NO_3$ as N (mg/ℓ)	NH_3 as N (mg/ℓ)	Phosphate total as P (mg/ℓ)
270901	max	12.4	810	8.50	165	0.130	0.300	0.207
	min	7.1	770	7.90	124	0.060	0.110	0.118
	mean	9.4	793	-	150	0.083	0.181	0.168
270902	max	12.0	800	8.70	164	0.120	0.260	0.166
	min	6.6	780	7.80	127	0.070	0.160	0.079
	mean	9.0	793	-	150	0.090	0.203	0.101
270903	max	11.0	840	8.70	179	0.150	0.640	0.203
	min	7.4	800	8.20	131	0.060	0.080	0.062
	mean	9.1	820	-	153	0.096	0.300	0.121
270904	max	10.0	980	8.10	196	0.[illegible]50	0.780	0.350
	min	7.0	870	7.97	181	0.060	0.110	0.153
	mean	8.2	930	-	189	0.220	0.383	0.240
Little Minnesota and Whetstone Rivers	approx	8.0-9.0	1,200	8.00	290-300	0.300-2.500	0.080-1.400	0.050-0.170

Source: Eutrophication Survey Branch, EPA, Corvallis, Oregon, 1974.

Although detailed descriptions of ground water recharge areas in the watershed are not available, recharge generally occurs throughout the uplands. Subsequent movement of the water underground is toward Big Stone Lake and its tributary valleys. One large area of shallow sand and gravel exists on the Minnesota side of Big Stone Lake and is a possible recharge area.[115/] Similar deposits are known to exist in the South Dakota portion of the watershed but their areal extent has not been determined.

When the water table intersects the land surface, such as in ravines and low areas, the ground water flows from springs or seepage areas. Numerous gravity springs which originate in shallow sand streaks or veins in the till (see Table 29), flow from the bluffs along the Minnesota side of Big Stone Lake north of Ortonville, Minnesota, and along the South Dakota shore north of Big Stone City.[1/]

Inflow from surface springs is an important factor in the water budget of Big Stone Lake. For example, during most of the Summer of 1967, Hartford Beach Creek was fed by a complex of springs located just west of the boundary of this South Dakota state park and not by surface runoff.[116/] This same situation occurs in many localities.

In addition to surface springs, there is some evidence that ground water may feed directly into the lake from buried sand and gravel deposits beneath the lake. In one locality a property owner indicated that springs are known to flow into the lake below the water surface near his land.[116/] The contribution of ground water from these subaqueous springs is unknown.

In addition to near surface sand and gravel deposits, ground water in the watershed is also available from more deeply buried lenses of sand and gravel which are located below the water table (see Table 29). These deposits have more widespread distribution, but have limited recharge compared to the shallow sand and gravel.

Where the Cretaceous rocks are thick and contain layers of sandstone, small quantities of water are available from the sandstone (see Table 29). Because of the westward slope of the Precambrian rock surface and associated thickening of the overlying Cretaceous sediments, conditions are more favorable for obtaining water from the Cretaceous rocks west of Big Stone Lake. This water may be confined under pressure by overlying and underlying deposits which prohibit free vertical circulation of the water (artesian water). Such artesian waters, when pressure is sufficiently great, will rise above the land surface when wells are drilled into formations containing them. There are a few flowing artesian wells in the Cretaceous sandstone near Brown's Valley, Minnesota.

Artesian wells have also been drilled in the buried sand and gravel lenses along the shore of Big Stone Lake.

A small number of wells obtain water from the weathered upper portions of the Precambrian basement rocks (see Table 29). Very little water is derived from the lower crystalline rocks.

Studies in the Big Stone Lake Watershed indicate that the ground water aquifers adjacent to the lake may supply significant amounts of water to the lake throughout the year. However, from available data the volume of water contributed to the lake from springs can only be estimated. Using meager data for the thickness of saturated deposits, contributing area, head difference, and vertical permeability, the U.S. Geological Survey estimated a ground water inflow to the lake of 18,800 acre-ft/year.[103/] On the other hand, an estimate of 15,300 acre-ft/year has been made using factors making up the water budget of the lake such as surface water inflow and outflow, direct precipitation, evaporation, and ground water inflow.[1/]

Adequate ground water supplies exist generally throughout the Big Stone Lake Watershed for municipalities. Projected water supply needs, primarily for Milbank, Sisseton, and Ortonville, South Dakota, can be satisfied by further development of ground water resources.[95/]

The source of most municipal and industrial supplies is the near surface sand and gravel. Yields from this aquifer are known to be as high as 1,200 gal/min (Table 29). On the other hand, the buried sand and gravel deposits generally do not have yields as high as the shallow deposits, but are better suited for rural domestic and stock supplies because they are more widespread. The Cretaceous sandstone generally yields only small quantities of water to wells. Locally, however, it may be the only ground water source and is used even though its quality is not satisfactory. Although supplies of water for irrigation are available locally, from all the aquifers, irrigation has been practiced very little in the watershed. The 1969 agricultural census showed that about 131 acres were irrigated and a total of 82 acre-ft of water was used in Big Stone and Roberts counties, the major land area in the watershed.[95/]

The surface and ground water resources of the watershed are summarized in Table 56. Of particular interest is the relative worth of the water resources for certain uses. For instance, Big Stone Lake is well suited, as are other surface water resources, for recreation and fish and wildlife habitat. The surface sand and gravel deposits can furnish good local municipal supplies while the buried sand and gravel is better suited for rural supplies.

TABLE 56

SUMMARY OF WATER RESOURCES IN THE BIG STONE LAKE WATERSHED

Use / Source	Major tributaries to Big Stone Lake	Reservoirs- Big Stone Lake	Small lakes and Minor streams	Near-surface sand and gravel	Buried sand and gravel	Cretaceous sandstone
Municipal and industrial supply	Favorable location Adequate flow with development of storage facilities ——— Storage necessary Treatment necessary No flow in droughts Flood damage	Favorable location Adequate storage capacity for present demand Adequate inflow Enlargement possible Treatment necessary Limited usable storage capacity without further development	Wide distribution ——— Limited capacity Limited inflow Many dry up in droughts Treatment necessary	Several favorable locations High well yields Rapid recharge ——— Limited distribution	Wide distribution ——— Limited recharge Low to moderate well yields	Fair distribution ——— Quality often unsuitable Low well yields
Rural-domestic and stock supply	Adequate for stock ——— Restricted areal distribution Treatment necessary for domestic use No flow during droughts	Adequate storage capacity Adequate inflow ——— Restricted areal distribution Treatment necessary	Wide distribution ——— Treatment necessary for domestic use Many dry up Limited inflow	Adequate well yields ——— Restricted areal distribution	Wide distribution Adequate well yields ———	Fair distribution Adequate well yields "Soft" water preferred by some Quality may be undesirable May be better water at shallower depth
Irrigation supply	Adequate flow with development of storage facilities ——— Storage required Low flow during irrigation season Restricted areal distribution	Adequate storage capacity Adequate inflow Enlargement possible Restricted areal distribution Limited usable storage capacity without further development	Wide distribution ——— Limited storage capacity Limited inflow Many dry up during irrigation season	High well yields Rapid recharge ——— Restricted areal distribution Soil formed on aquifer may be too permeable to irrigate	Wide distribution ——— Limited recharge Low to moderate yields	Fair distribution ——— Limited recharge Low yields Quality often unsuitable
Recreation	Favorable location Suitable for fishing and hunting ———	Adequate area and depth Favorable for hunting and watersports Camping sites at parks Enlargement possible ———	Wide distribution Favorable for watersports on a few lakes Hunting areas on many lakes and swamps ——— Shallow Many dry up during droughts			
Fish and wildlife habitat	Suitable for wildlife along banks ——— Variable streamflow	Marsh areas suitable for wildlife habitat Conservation pools maintained ——— Floods	Scattered marsh areas Excellent for wildlife habitat ——— Shallow Many dry up			

Note: Table modified from U.S. Geological Survey Hydrologic Atlas HA-213, 1966.

b. Quality: Most of the water for farmstead use comes from wells. Water which comes from deep wells is more likely to be free of pathogenic organisms than from springs or shallow wells because deep wells are less likely to be affected by surface contamination.2/

Some general parameters considered in assessing ground water quality are: pH; taste and odor; color; temperature; total dissolved inorganic solids; dissolved organic compounds (especially chlorinated hydrocarbons); turbidity; trace elements; radionuclides; and pathogenic and nonpathogenic microorganisms.2/ A number of the recommended parameters have no available data for this study area.

The National Technical Advisory Committee2/ provides the following recommendations for farmstead waters:

CHLORINATED ORGANIC PESTICIDES

Compound	Maximum Acceptable Concentration (µg/liter)
Endrin	1.0
Aldrin	17.0
Dieldrin	17.0
Lindane	56.0
Toxaphene	5.0
Heptachlor	18.0
H. epoxide	18.0
DDT	42.0
Chlordane	3.0
Methoxychlor	35.0

Trace Ions		Trace Substances	
Substance	Maximum Limit (mg/liter)	Substances	Recommended Limit (mg/liter)
Arsenic	0.05	Manganese	0.05
Barium	1.00	Iron	0.30
Cadmium	0.01	Copper	1.00
Chromium (Hexa)	0.05	Zinc	5.00
Cyanides	0.20	Fluoride	0.7-1.20
Lead	0.05	Nitrate (NO_3)	45.00
Selenium	0.01	Nitrate (N)	10.00
Silver	0.05		

Examples of ground water data in the Big Stone Lake Watershed are shown in Tables 57 and 58 (Otter Tail Power Company Survey, Dorand Engineering Services, Brookings, South Dakota, 1973); and Table 59 (U.S. Geological Survey, 1966).

(1) Water quality data for 10 wells in the Big Stone Power Plant area (Tables 57 and 58)

Specific conductance: Values for the 10 wells range from about 1,050-2,600 µmhos/cm. Such values indicate extremely high concentrations of dissolved inorganic chemicals. These values are considerably higher than the lake water.

Total hardness as $CaCO_3$: Waters from the 10 wells range from about 500-1,600 mg/liter as $CaCO_3$. Two of the wells (Nos. 3 and 9) have hardness values more near that of surface waters but in general these wells show values higher than those for surface waters.

Calcium hardness as $CaCO_3$: The most common anions responsible for hardness are bicarbonates, sulfates, and chlorides. Calcium, magnesium, and sodium are usually the predominant cations in ground water. The 10 wells show that the calcium cation contributes greatly to the water hardness of ground water.

Total alkalinity: Alkalinity is a measure of the carbonate and bicarbonate ion. The total alkalinity for the 10 wells is probably the result of the bicarbonate ion as other wells in the watershed (Table 59) show this to be true. Precipitation of the calcium compounds is rapid where the bicarbonate anion is present and causes problems in water systems by causing deposits to form in pipes and leaves deposits on milk handling equipment.

Sulfates: This anion is extremely high. A threshold limit of 1,000 mg/liter is recommended for drinking purposes.[2/] Two of these wells are at or slightly above the threshold.

Total phosphorus as P: The total phosphorus concentrations are above levels that could cause algal bloom in surface waters and are either the result of perculated surface water or result from some natural source.

Nitrate nitrogen: For drinking water the U.S. Public Health Service[110/] recommends a maximum of 45 mg/liter as NO_3 or about 10 mg/liter as N. The wells are within these limits; however, two wells (Nos. 4 and 5) show signs of contamination from surface pollutants or agricultural runoff.

TABLE 57

MEAN CONCENTRATIONS OF CHEMICAL CONSTITUENTS FOR SAMPLES FROM 10 WELLS
BIG STONE POWER PLANT AREA
(November 1971-November 1972)

Determination[a]	Well Number Location[b]									
	0	1	2	3	4	5	6	7	8	9
Conductivity - µmhos/cm-25°C	1700	1710	2580	1052	2630	1770	1503	1440	1513	1133
Total Hardness ($CaCO_3$)	880	981	1604	507	1577	983	827	781	814	535
Calcium Hardness ($CaCO_3$)	620	694	1106	308	1144	538	519	494	568	355
Total Alkalinity ($CaCO_3$)	437	427	442	309	457	479	465	435	440	273
Chlorides (Cl)	1.8	1	31.7	2.6	39.8	19.6	1.8	1.4	1.1	11.5
Sulfates (SO_4)	563	613	1154	272	1093	450	409	400	439	330
Total Phosphorous (P)	0.05	0.09	0.06	0.05	0.06	0.01	0.05	0.05	0.02	0.03
Nitrate Nitrogen (N)	0.2	0.0	0.8	0.02	12.8	22.0	0.0	0.0	0.0	0.2
Ammonia Nitrogen (N)	1.63	0.49	0.8	3.28	0.82	0.21	0.55	0.95	0.94	0.57
Kjeldahl Nitrogen (N)	1.6	0.6	1.0	3.4	1.0	0.6	0.8	1.1	1.0	0.9
Total Residue	1342	1445	2397	792	2380	1406	1164	1147	1198	873
pH - units (median)	6.9	7.0	6.9	7.3	6.7	7.0	7.0	7.1	7.0	7.0

a/ Results expressed as mg/ℓ except as noted.
Source: Otter Tail Power Company Study, Dorand Engineering Services, Brookings, South Dakota (1972).
b/ See Figure 6

TABLE 58

MEAN CONCENTRATIONS OF CHEMICAL CONSTITUENTS FOR SAMPLES FROM 10 WELLS

BIG STONE PLANT

(December 1972-December 1973)

Determination[a]	Well Number 0	1	2	3	4	5	6	7	8	9
Conductivity - µmhos/cm-25°C	1667	1997	2783	1287	2722	1651	1435	1378	1494	1133
Total Hardness ($CaCO_3$)	894	1148	1682	528	1626	900	768	705	756	505
Calcium Hardness ($CaCO_3$)	583	776	1226	315	1224	553	477	439	565	322
Sodium	33	18	32	72	24	25	23	28	23	42
Total Alkalinity ($CaCO_3$)	424	413	414	338	433	464	460	415	431	258
Chlorides (Cl)	1.5	1.4	34.8	2.4	41.5	6.3	2.3	2.2	1.5	15.1
Sulfates (SO_4)	605	813	1320	372	1160	489	394	372	412	314
Total Phosphorus (P)	0.06	0.08	0.03	0.02	0.00	0.01	0.03	0.03	0.02	0.02
Nitrate Nitrogen (N)	0.3	0.0	6.7	0.5	23.9	5.3	0.0	0.0	0.0	0.1
Ammonia Nitrogen (N)	1.95	0.76	0.67	3.96	0.96	0.38	0.53	1.01	1.03	0.55
Kjeldahl Nitrogen (N)	2.2	1.2	1.6	4.8	1.5	0.7	0.8	1.3	1.3	1.0
Total Residue	1382	1797	2667	947	2588	1347	1149	1139	1199	852
pH - units (median)	7.0	7.0	6.9	7.2	6.7	7.0	7.0	7.1	7.0	7.1

a/ Results expressed as mg/ℓ except as noted.

Source: Otter Tail Power Company Study, Dorand Engineering Services, Brookings, South Dakota (1973).

TABLE 59

GROUND WATER CHEMICAL ANALYSES FOR WELLS FROM THREE AQUIFERS IN THE BIG STONE LAKE AREA

Location	Date of Collection	Depth of Well (ft)	Temperature (°F)	Silica (SiO_2) (mg/l)	Iron (Fe) (mg/l)	Manganese (Mn) (mg/l)	Calcium (Ca) (mg/l)	Magnesium (Mg) (mg/l)	Sodium (Na) (mg/l)	Potassium (K) (mg/l)
Pleistocene--Near Surface Sand and Gravel										
NW 1/4 NW 1/4 SW 1/4, Sec. 16, T. 121 N., 246 W.	9/27/63	71	51	31	2.5	0.24	171	76	47	11
NE 1/4 NW 1/4 NE 1/4, Sec. 29, T. 119 N., R. 44 W.	10/17/63	16	48	28	0.05	0.68	369	272	83	11
Pleistocene--Buried Sand and Gravel										
SW 1/4 NE 1/4 NE 1/4, Sec. 6, T. 118 N., R. 46 W.	10/16/63	140	--	23	13.0	0.16	322	167	58	10
SE 1/4 NW 1/4 SE 1/4, Sec. 16, T. 123 N., R. 46 W.	10/3/63	335	49	29	1.8	0.09	92	50	206	5.5
Cretaceous Sandstone										
SW 1/4 SE 1/4 SW 1/4, Sec. 4, T. 124 N., R. 49 W.	10/2/63	400	--	8.8	2.2	0.00	21	15	1,230	8.2
NE 1/4 NE 1/4 SE 1/4, Sec. 35, T. 119 N., R. 46 W.	10/17/63	293	--	6.3	5.0	0.06	37	11	1,170	11

TABLE 59 (Continued)

GROUND WATER CHEMICAL ANALYSES FOR WELLS FROM THREE AQUIFERS IN THE BIG STONE LAKE AREA

Location	Date of Collection	Bicarbonate (HCO_3) (mg/ℓ)	Carbonate (CO_3) (mg/ℓ)	Sulfate (SO_4) (mg/ℓ)	Chloride (Cl) (mg/ℓ)	Fluoride (F) (mg/ℓ)	Nitrate (N) (mg/ℓ)
Pleistocene--Near Surface Sand and Gravel							
NW 1/4 NW 1/4 SW 1/4, Sec. 16, T. 121 N., 246 W.	9/27/63	638	0	244	32	0.2	4.50
NE 1/4 NW 1/4 NE 1/4 Sec. 29, T. 119 N., R. 44 W.	10/17/63	584	0	1,400	86	0.3	45.10
Pleistocene--Buried Sand and Gravel							
SW 1/4 NE 1/4 NE 1/4, Sec. 6, T. 118 N., R. 46 W.	10/16/63	494	0	1,160	1.0	0.4	0.07
SE 1/4 NW 1/4 SE 1/4, Sec. 16, T. 123 N., R. 46 W.	10/3/63	438	0	432	26	0.6	1.22
Cretaceous Sandstone							
SW 1/4 SE 1/4 SW 1/4, Sec. 4, T. 124 N., R. 49 W.	10/2/63	453	0	1,330	704	5.2	2.70
NE 1/4 NE 1/4 SE 1/4, Sec. 35, T. 119 N., R. 46 W.	10/17/63	381	0	1,300	705	2.9	0.07

Selected Chemical Analyses of Ground Water (continued)

TABLE 59 (Concluded)

GROUND WATER CHEMICAL ANALYSES FOR WELLS FROM THREE AQUIFERS IN THE BIG STONE LAKE AREA

Location	Date of Collection	Boron (B) (mg/ℓ)	Dissolved Solids (mg/ℓ)	Calcium Magnesium (mg/ℓ)	Hardness as $CaCO_3$ non-carbonate (mg/ℓ)	Specific Conductance (µmhos/cm)	pH (units)	Color (Pt-Co units)	% Sodium	Sodium Adsorption Ratio
Pleistocene--Near Surface Sand and Gravel										
NW 1/4 NW 1/4 SW 1/4 Sec. 16 T. 121 N., 246 W.	9/27/63	0.26	973	741	218	1,430	7.9	--	12	0.7
NE 1/4 NW 1/4 NE 1/4 Sec. 29, T. 119 N., R. 44 W.	10/17/63	0.21	2,930	2,040	1,560	3,170	7.8	--	8	0.8
Pleistocene--Buried Sand and Gravel										
SW 1/4 NE 1/4 NE 1/4 Sec. 6, T. 118 N., R. 46 W.	10/16/63	0.53	2,140	1,490	1,080	2,400	7.7	--	8	0.7
SE 1/4 NW 1/4 SE 1/4 Sec. 16, T. 123 N., R. 46 W.	10/3/63	0.86	1,150	434	75	1,620	7.8	--	50	4.3
Cretaceous Sandstone										
SW 1/4 SE 1/4 SW 1/4 Sec. 4, T. 124 N., R. 49 W.	10/2/63	4.00	3,630	113	0	5,360	8.0	--	96	50
NE 1/4 NE 1/4 SE 1/4 Sec. 35, T. 119 N., R. 46 W.	10/17/63	4.3	3,470	139	0	5,240	8.1	--	94	43

Selected Chemical Analysis of Ground Water (concluded)

Ammonia nitrogen: The presence of ammonia nitrogen is sometimes used as evidence of organic pollution in waters. Mean values for all 10 wells for the years 1971-73 (Tables 57 and 58) range from 0.21-3.96 mg/liter N. These 10 wells show definite evidence of pollution from surface waters. No depths are shown for these wells but they are probably rather shallow.

Kjeldahl nitrogen: Kjeldahl values include both ammonia nitrogen and organic nitrogen. This evaluation also shows definite signs of organic pollution for the 10 wells.

Total residue: Total residue values include both soluble and filterable materials. Total solids values are extremely high. Soluble minerals constitute most of the total residue which is evident from conductivity, hardness, calcium, and sulfate values.

pH: Median values for pH are near neutrality.

(2) Ground water analyses for wells from three aquifers in the Minnesota portion of the Big Stone Lake Watershed: Examples of ground water from three aquifers (near surface sand and gravel--16-71 ft depths, buried sand and sandstone--293-400 ft depths) are shown in Table 59. Parameters having specific recommended limits are assessed.

Iron: The recommended limit[2/] is 0.30 mg/liter. Water used in milkhouse sanitation should not contain more than 0.10 mg/liter of either iron or copper. Five of the six wells from the three aquifers show iron concentrations in excess of the recommended concentration.

Manganese: The recommended limit[2/] is 0.05 mg/liter. Five of the six wells exceed the recommended concentration.

Sulfates: The recommended maximum sulfate concentration is 1,000 mg/liter[2/] but if no other source of water is available higher concentrations are used. Four of the six wells exceed 1,000 mg/liter sulfates.

Fluoride: The recommended limit is 0.7-1.2 mg/liter. Water containing more than 2.5 mg/liter fluoride is detrimental to tooth formation.[2/] Two of the wells from the Cretaceous sandstone formation exceed this 2.5 mg/liter value.

Nitrates: One of the shallow wells (16-ft depth) shows about 46.12 mg/liter nitrate (N) concentration. This is over four times the recommended level. Perculation of surface waters undoubtedly accounts for this high nitrate level.

Dissolved solids: Although not covered by specific limitations, five of these six wells show exceptionally high values for dissolved solids. These waters from all aquifers contain relatively high levels of calcium, magnesium, sodium sulfates, and bicarbonates. The high inorganic minerals content is also reflected by high specific conductance values (1,400-5,000 µmhos/cm).

(3) Summary of ground water: The data covering physical and chemical analyses on ground water show these waters contain high concentrations of calcium, magnesium, sulfates, and sometimes sodium. The waters are generally quite hard (greater than 1,000 mg/liter as $CaCO_3$) and those shown in Table 59 generally contain iron and manganese in excess of the maximum recommended level.[2/]

Phosphate concentrations (Tables 57 and 58) are 0.01-0.09 mg/liter as P which indicates that this element is a result of surface contamination or comes from phosphate containing glacial deposits.

Nitrogen sources (organic and inorganic) are present in ground waters (Tables 57 and 58). The presence of organic nitrogen indicates that waters are contaminated from solubles in surface waters.

Ground water in the Big Stone Lake Watershed could be rated with acceptable quality as no better source is available. However, the ground water quality fails to meet recommended maximum concentrations for several parameters.

4. Detectable changes in water quality with particular reference to nitrogen and phosphate concentrations: Uncontrolled or very limited control of human activities can result in the enrichment of a water body with plant nutrients, a process referred to as eutrophication (Figure 15 for simplified schematic illustration). The most unfavorable consequence of eutrophication is not the direct effect of the nutrients themselves, but the side effects resulting in excessive growth of aquatic plants including algae. In recreational lakes algae accumulations can impair aesthetic qualities as well as cause deterioration in fisheries.[114/]

Both major plant nutrients and available nitrogen and phosphorus compounds have been identified as essential nutrients for excessive algal blooms where optimum concentrations are available in conjunction with optimum light, temperature, and other minerals and trace minerals.[114/] Phosphorus is generally considered to be the limiting nutrient and that most adaptable to regulating for dealing with nuisance aquatic plant growth.

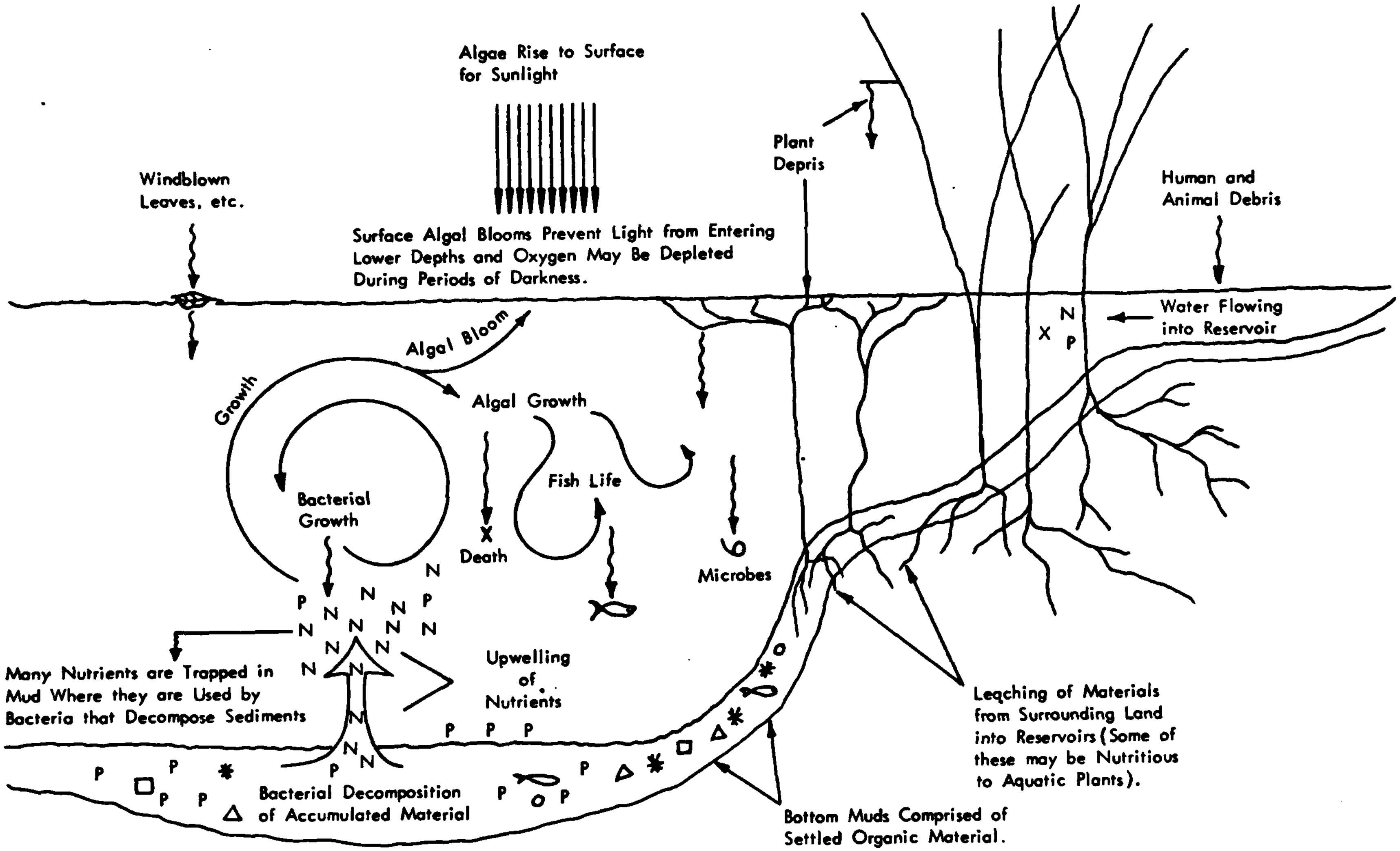


Figure 15 - Schematic Presentation of Some Major Cycles in Impounded Water Supplies

Phosphorus is naturally available from the weathering of rocks and from the soil. It is also present in chemical fertilizers, sewage, and animal waste products, but in much smaller quantities than nitrogen. In the presence of oxygen, phosphorus is precipitated from solution as ferric phosphate.[70/] During the summer, a precipitator of calcium phosphate may also be formed. Overall, the net flow of phosphorus is into the sediments.[72/] This means that the bottom sediments of most lakes and ponds are very rich in phosphorus while the water column may be, under certain conditions, phosphorus deficient. Bottom sediments collected from the lower portion of Big Stone Lake in 1973 (Table 60) show analyses for high phosphorus concentrations (essentially bound phosphorus) and organic nitrogen. This nutrient reservoir of sediment has accumulated to approximately 10-ft depths in the lower end of the lake.

The Big Stone Lake Study[1/] provides a history of aquatic plant growth in the lake which appears to reach a nuisance category approximately in 1958. In the following 10 years through 1967, indications progressively point to more intense stands of aquatic plants (weeds) and algal blooms.[1/]

Nitrogen and phosphorus analyses for Big Stone Lake are very minimal prior to 1958. However, during 1958-59 (Table 51) total phosphate concentrations as (P) reached a maximum of 3.600 mg/liter. Only nitrate nitrogen (N) was reported for that year which, no doubt, accounted for only a fraction of the available nitrogen. The phosphate and probable nitrogen concentrations would confirm the nuisance plant growth in the lake in 1958-59. An investigation stemming from pollution complaints was conducted by the Minnesota Department of Health in 1959.[77/]

This report concluded that major sources of pollution of the Whetstone River entering the Big Stone Lake was from the Big Stone Cheese Factory and possibly pollution of the river by a septic drain connecting several residences to this common drain to the river. Compounding the problem was the very slow flow of the Whetstone River[77/] and maintaining a constant water level in Big Stone Lake by gates in the dam. This practice was initiated in 1958.[1/] At low stream flow most of the pollutants went into the lake. At this time, no reports had identified livestock operations with lake pollution.

Any trend for assessing water quality parameters prior to 1958 is difficult to substantiate. Available data where samples were taken at the same station over a period of years and more than once annually are those provided by Storet Retrieval, Environmental Protection Agency. Those data for nitrogen and phosphate concentrations are shown in a yearly progression in Table 51. Failure in analyzing the same nitrogen parameters through the years 1958-73 does not allow for assessments for total nitrogen.

TABLE 60

SEDIMENT SAMPLE ANALYSES[a/] (NITROGEN AND PHOSPHORUS) FOR LOWER PORTION OF BIG STONE LAKE--JUNE, 1973

Ammonia as (N) ppm (Dry wt)	Kjeldahl Nitrogen (N) ppm (Dry Wt)	Nitrate Nitrogen (N) ppm (Dry Wt)	Orthophosphate (P) ppm (Dry Wt)	Total Phosphate (P) ppm (Dry Wt)
65	780	0.23	27.7	943

a/ Average values for four probe samples and various sections of each probe sample.

Source: Serco Sanitary Engineering Laboratories, Inc., Minneapolis, Minnesota 1973.

Based on the water quality data at the Big Stone Lake Dam in Table 51, approximate yearly averages for ammonia nitrogen (N), nitrate nitrogen (N), total nitrogen (N), and total phosphate (P) were used to construct Table 61. Graphic presentations for ammonia nitrogen (N), nitrate nitrogen (N), and total phosphate (P) are shown in Figure 16.

From the data presented (Table 61 and Figure 16) ammonia nitrogen (N) concentrations at the Big Stone Lake Dam show an increase from 1961-64 values when compared with values from 1969-73. The peak average concentration occurred in 1968 (1.5 mg/liter).

Nitrate nitrogen data in 1958-59 (Table 61 and Figure 16) shows a trend for increased concentrations from 1967-73. A peak average concentration is reported for 1967 (0.5 mg/liter).

Total phosphorus (P) concentrations 1958-59, 0.48 and 2.16 mg/liter, are the highest values shown (Table 61 and Figure 16). From the year 1962 to the present time, 1974, a rather constant range (0.2-0.3 mg/liter) is apparent. From the year 1968 to the present, 1974, an increased concentration is apparent for 1972, 1973, and the limited data for 1974. From the data presented, the total time period 1958-73 shows a decrease in phosphorus concentration but a short-term view shows an increase from 1968-73.

To summarize the nutrient changes in water quality for Big Stone Lake (nitrogen and phosphorus constituents) the following indications are apparent:

1. An increase in average ammonia nitrogen evident from 1970-73,

2. An increase in nitrate nitrogen is evident from 1968-73, and

3. An increase in total phosphorus is evident from 1968-73.

In conclusion, the major nutrient load for Big Stone Lake is derived from:

1. The Whetstone River

2. The Little Minnesota River

3. Fish Creek and tributaries in the Minnesota portion of the watershed

4. The biological regeneration of organic nutrients in the sediment of Big Stone Lake

Furthermore, it is highly probable that ground water feeding the lake serves as a natural source of phosphorus.

TABLE 61

AVERAGE YEARLY CONCENTRATIONS FOR NITROGEN AND PHOSPHORUS NUTRIENTS AT BIG STONE LAKE DAM

Date	Ammonia nitrogen (N) (mg/ℓ)	Nitrate nitrogen (N) (mg/ℓ)	Total nitrogen (N) (mg/ℓ)	Total Phosphorus (p) (mg/ℓ)
1958	--	0.20	--	0.480
1959	--	0.06	--	2.160
1960	--	--	--	--
1961	0.24	--	--	--
1962	0.23	--	--	0.222
1963	--	--	--	0.330
1964	0.09	--	--	0.270
1965	0.59	--	--	0.296
1966	--	--	--	--
1967	0.13	0.51	2.24	0.250
1968	1.51	0.11	2.55	0.180
1969	0.48	0.25	1.99	0.198
1970	0.27	0.21	1.68	0.190
1971	0.35	0.19	2.24[a/]	0.195
1972	0.31	0.27	1.49[b/]	0.324
1973	0.48	0.30	2.01[c/]	0.215
1974 (Jan.)	0.47	0.31	2.18	0.250

Source: Table 51.

a/ 6 months data available
b/ 1 month data available
b/ 3 months data available

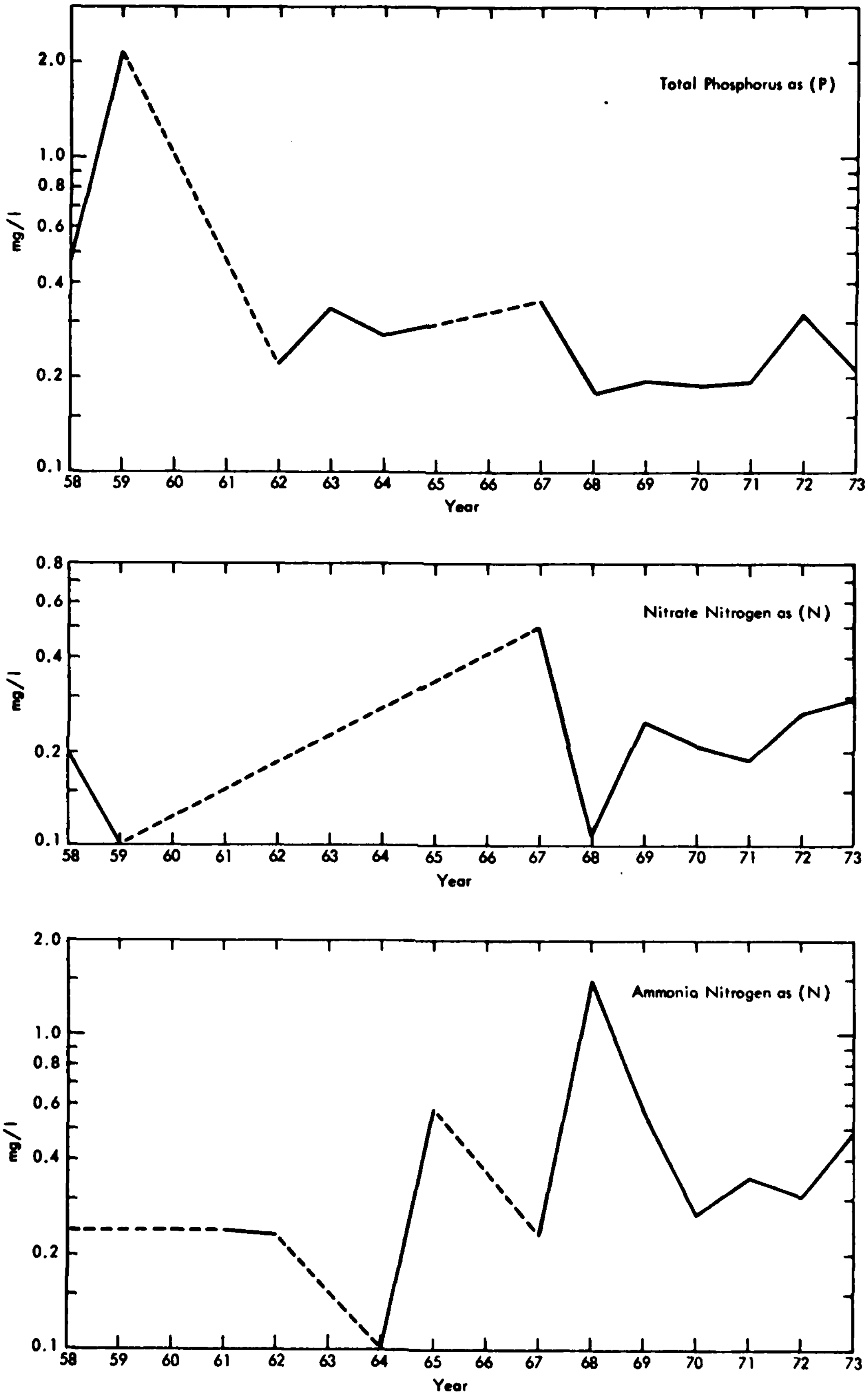


Figure 16 - Yearly Average Values for Ammonia Nitrogen, Nitrate Nitrogen and Total Phosphorus at Big Stone Lake Dam

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APPENDIX A

NATIVE TREES OF BIG STONE WATERSHED

NATIVE TREES OF BIG STONE LAKE WATERSHED

Black Willow	*Salix niger*
Quaking Aspen	*Populus tremuloides*
Bigtooth Cottonwood	*Populus tacamahaca*
Eastern Cottonwood	*Populus deltoides*
Black Walnut	*Juglans nigra*
Butternut	*Juglans cineria*
Paper Birch	*Betula paprifera*
Bur Oak	*Quercus macrocarpa*
American Elm	*Ulmus americana*
Slippery Elm	*Ulmus fulva*
Rock Elm	*Ulmus thomasi*
Hackberry	*Celtis occidentalis*
Red Maple	*Acer rubrum*
Boxelder	*Acer negundo*
Basswood	*Telia americana*
Red Ash (Green Ash)	*Fraxinus pennsylvanica*

Source: Harlow, William M. and Ellwood S. Harrar, *Textbook of Dendrology*, McGraw-Hill Book Co., New York (1950).

APPENDIX B

AMPHIBIANS AND REPTILES WITH A GEOGRAPHICAL RANGE[14]
WHICH INCLUDES BIG STONE WATERSHED

AMPHIBIANS AND REPTILES WITH A GEOGRAPHICAL RANGE[14/] WHICH INCLUDES BIG STONE WATERSHED

Snapping Turtle	Chelydra serpentina
Painted Turtle	Chrysemys picta
Spiny Softshell	Trionyx spinifer
Six-Lined Racerunner	Cnemidophorus sexlineatus
Prairie Skink	Eumeces septentrionalis
Red-Bellied Snake	Storeria occipitomaculata
Eastern Garter Snake	Thamnophis sirtalis
Plains Garter Snake	T. radix
Western Hognose Snake	Heterodon nasicus
Smooth Green Snake	Opheodrys vernalis
Fox Snake[a/]	Elaphe vulpina
Bullsnake[a/]	Pituophis melanoleucus
Mudpuppy	Necturus maculosus
Tiger Salamander	Ambystoma tigrinum
American Toad	Bufo americanus
Great Plains Toad	Bufo cognatus
Cricket Frog[a/]	Acris crepitans
Chorus Frog	Pseudacris triseriata
Leopard Frog	Rana pipiens

Note: None of the above species are threatened or endangered.[15/]
Source: Ref. 16 and 17.
a/ May or may not be found in this watershed; this watershed is on perimeter of range.

SPECIES	HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS					EFFECT OF PROJECT ACTION						
	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Abundant or Common	Uncommon	Occasional	Rare	Rare or Endangered	Highly Detrimental	Moderately Detrimental	Slightly Detrimental	Present Status or No Apparent Impact	Slightly Advantageous	Moderately Advantageous	Highly Advantageous
Mudpuppy <u>Necturus maculosus</u>	X										X		X										
Tiger Salamander <u>Ambystoma tigrinum</u>					X	X	X	X	X			X											
American Toad <u>Bufo americanus</u>	X	X	X	X	X	X	X	X					X										
Great Plains Toad <u>Bufo cognatus</u>	X	X	X		X	X	X						X										
Cricket Frog <u>Acris crepitans</u>	X	X	X											X									
Chorus Frog <u>Pseudacris triseriata</u>	X	X	X										X										
Leopard Frog <u>Rana pipiens</u>	X	X	X		X		X					X											
Six-Lined Racerunner <u>Cnemidophorus sexlineatus</u>				X	X		X							X									
Prairie Skink <u>Eumeces septentrionalis</u>							X	X	X	X	X		X										
Western Hognose Snake <u>Heterodon nasicus</u>				X	X	X	X						X	X									
Smooth Green Snake					X	X	X						X										

SPECIES	HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS					EFFECT OF PROJECT ACTION						
	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Abundant or Common	Uncommon	Occasional	Rare	Rare or Endangered	Highly Detrimental	Moderately Detrimental	Slightly Detrimental	Present Status or No Apparent Impact	Slightly Advantageous	Moderately Advantageous	Highly Advantageous
Fox Snake *Elaphe vulpina*		X	X		X	X	X						X										
Bullsnake *Pituophis melanoleucus*				X	X	X	X						X										
Red-bellied Snake *Storeria occipitomaculata*								X	X		X		X										
Plains Garter Snake *Thamnophis radix*		X	X	X	X	X	X						X										
Eastern Garter Snake *Thamnophis sirtalis*		X		X	X	X	X	X			X	X											
Snapping Turtle *Chelydra serpentina*	X		X										X										
Painted Turtle *Chrysemys picta*	X	X	X										X										
Spiny Softshell *Trionyx spinifer*	X												X										
Source: 16,17/																							

APPENDIX C

MAMMALS WITH A GEOGRAPHICAL RANGE
WHICH INCLUDES THE BIG STONE WATERSHED

MAMMALS WITH A GEOGRAPHICAL RANGE WHICH INCLUDES THE BIG STONE WATERSHED

Masked Shrew	Sorex cinereus
Arctic Shrew	S. arcticus
Northern Water Shrew	S. palustris
Pigmy Shrew	Microsorex hoyi
Shorttail Shrew	Blarina brevicauda
Eastern Mole	Scalopus aquaticus
Little Brown Myotis	Myotis lucifugus
Keen Myotis	M. keeni
Silver-Haired Bat	Lasionycteris noctivagans
Big Brown Bat	Eptesicus fuscus
Red Bat	Lasiurus borealis
Hoary Bat	L. cinereus
Raccoon	Procyon lotor
Shorttail Weasel	Mustela erminea
Least Weasel	M. rixosa
Longtail Weasel	M. frenata
Mink	M. vison
River Otter	Lutra canadensis
Badger	Taxidea taxus
Spotted Skunk	Spilogale putorius
Striped Skunk	Mephitis mephitis
Coyote	Canis latrans
Red Fox	Vulpes fulva
Gray Fox	Urocyon cinereoargenteus
Bobcat	Lynx rufus
Woodchuck	Marmota monax
Thirteen-Lined Ground Squirrel	Citellus tridecemlineatus
Richardson Ground Squirrel	C. richardsonii
Franklin Ground Squirrel	C. franklini
Eastern Chipmunk	Tamias striatus
Eastern Gray Squirrel	Sciurus carolinensis
Eastern Fox Squirrel	Sciurus niger
Red Squirrel	Tamiasciurus hud[illegible]
Northern Flying Squirrel	Glaucomys [illegible]
Plains Pocket Gopher	Geomys bursar[illegible]
Plains Pocket Mouse	Per[illegible]
Beaver	Cast[illegible]

AD-A120 747 NATURAL RESOURCES STUDY TO DETERMINE CAUSES AND ALTERNATIVE SOLUTIONS TO T..(U) MIDWEST RESEARCH INST KANSAS CITY MO AUG 74 DACW37-74-C-0107 3/3

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MICROCOPY RESOLUTION TEST CHART
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Western Harvest Mouse	Reithrodontomys megalotis
Deer Mouse	Peromyscus maniculatus
White-Footed Mouse	P. leucopus
Northern Grasshopper Mouse	Onychomys leucogaster
Southern Bog Lemming	Synaptomys cooperi
Boreal Redback Vole	Clethrionomys gapperi
Meadow Vole	Microtus pennsylvanicus
Prairie Vole	M. ochrogaster
Muskrat	Ondatra zibethica
Norway Rat	Rattus norvegicus
House Mouse	Mus musculus
Meadow Jumping Mouse	Zapus hudsonius
Western Jumping Mouse	Z. princeps
Whitetail Jackrabbit	Lepus townsendi
Eastern Cottontail	Sylvilagus floridanus
Snowshoe Hare	Lepus americanus
Mule Deer	Odocoileus hemionus
Whitetail Deer	Odocoileus virginianus

Source: Refs. 14, 18, 21 and 22.

SPECIES	HABITAT PREFERENCE AND RESTRICTIONS: Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	PRESENT POPULATION LEVELS: Abundant or Common	Uncommon	Occasional	Rare	Rare or Endangered	EFFECT OF PROJECT ACTION: Highly Detrimental	Moderately Detrimental	Slightly Detrimental	Present Status or No Apparent Impact	Slightly Advantageous	Moderately Advantageous	Highly Advantageous
Masked Shrew - Sorex cinereus		X		X	X	X	X	X	X				X										
Arctic Shrew - Sorex arcticus			X											X									
Northern Water Shrew - Sorex palustris	X		X											X									
Pygmy Shrew - Microsorex hoyi														X									
Short-Tailed Shrew - Blarina brevicauda		X		X	X	X	X	X	X				X										
Little Brown Myotis - Myotis lucifugus								X	X			X											
Keen Myotis - Myotis keeni								X	X					X									
Silver-Haired Bat - Lasionycteris noctivagans								X	X						X								
Big Brown Bat - Eptesicus fuscus								X	X					X									
Red Bat - Lasiurus borealis								X	X					X									

SPECIES	HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS					EFFECT OF PROJECT ACTION						
	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Abundant or Common	Uncommon	Occasional	Rare	Rare or Endangered	Highly Detrimental	Moderately Detrimental	Slightly Detrimental	Present Status or No Apparent Impact	Slightly Advantageous	Moderately Advantageous	Highly Advantageous
Hoary Bat - *Lasiurus ciner*								X	X					X									
Raccoon - *Procyon lotor*			X					X	X			X											
Shorttail Weasel - *Mustela erminea*							X	X	X				X										
Least Weasel - *Mustela rixosa*					X		X	X	X				X										
Longtail Weasel - *Mustela frenata*	X	X												X									
Mink - *Mustela visor*	X												X										
River Otter - *Lutra canadensis*	X													X									
Badger - *Taxidea taxus*					X	X	X							X									
Spotted Skunk - *Spilogale putorius*								X	X					X									
Striped Skunk - *Mephitus mephitus*				X	X	X	X	X	X		X	X											

SPECIES	HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS					EFFECT OF PROJECT ACTION						
	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Abundant or Common	Uncommon	Occasional	Rare	Rare or Endangered	Highly Detrimental	Moderately Detrimental	Slightly Detrimental	Present Status or No Apparent Impact	Slightly Advantageous	Moderately Advantageous	Highly Advantageous
Coyote - <u>Canis</u> <u>latrans</u>						X	X	X						X									
Red Fox - <u>Vulpes</u> <u>fulva</u>				X	X	X	X	X	X					X									
Gray Fox - <u>Urocyon</u> <u>cinereoargenteus</u>								X						X									
Bobcat - <u>Lynx</u> <u>rufus</u>			X						X					X									
Woodchuck - <u>Marmota</u> <u>monax</u>								X	X					X									
Richardson Ground Squirrel - <u>Citellus</u> <u>richardsoni</u>					X	X							X										
Thirteen-Lined Ground Squirrel - <u>Citellus</u> <u>tridecemlineatus</u>					X	X							X										
Franklin Ground Squirrel - <u>Citellus</u> <u>franklini</u>		X			X		X	X						X									
Eastern Chipmunk - <u>Tamias</u> <u>striatus</u>								X	X					X									
Eastern Gray Squirrel - <u>Sciurus</u> <u>carolinensis</u>									X					X									

SPECIES	HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS					EFFECT OF PROJECT ACTION						
	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Abundant or Common	Uncommon	Occasional	Rare	Rare or Endangered	Highly Detrimental	Moderately Detrimental	Slightly Detrimental	Present Status or No Apparent Impact	Slightly Advantageous	Moderately Advantageous	Highly Advantageous
Eastern Fox Squirrel - <u>Sciurus niger</u>									X					X									
Red Squirrel - <u>Tamiasciurus hudsonicus</u>			X							X	X			X									
Northern Flying Squirrel - <u>Glaucomys sabrinus</u>										X	X		X										
Plains Pocket Gopher - <u>Geomys bursarius</u>				X	X	X	X							X									
Plains Pocket Mouse - <u>Perognathus flavescens</u>						X								X									
Beaver - <u>Castor canadensis</u>	X	X							X				X										
Western Harvest Mouse - <u>Reithrodontomys megalotis</u>		X			X	X							X										
Deer Mouse - <u>Peromyscus maniculatus</u>				X	X	X	X	X	X			X											
White-Footed Mouse - <u>Peromyscus leucopus</u>							X	X	X			X											
Northern Grasshopper Mouse - <u>Onychomys leucogaster</u>					X	X	X						X										

SPECIES	HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS					EFFECT OF PROJECT ACTION						
	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Abundant or Common	Uncommon	Occasional	Rare	Rare or Endangered	Highly Detrimental	Moderately Detrimental	Slightly Detrimental	Present Status or No Apparent Impact	Slightly Advantageous	Moderately Advantageous	Highly Advantageous
Southern Bog Lemming - <u>Synaptomys cooperi</u>		X	X											X									
Boreal Redback Vole - <u>Clethrionomys gapperi</u>									X	X	X			X									
Meadow Vole - <u>Microtus pennsylvanicus</u>		X	X				X	X				X											
Prairie Vole - <u>Microtus ochrogaster</u>						X	X							X									
Muskrat - <u>Ondatra zibethica</u>	X	X										X											
Norway Rat - <u>Rattus norvegicus</u>	Populated Areas											X											
House Mouse - <u>Mus musculus</u>	Populated Areas											X											
Western Jumping Mouse - <u>Zapus princeps</u>		X												X									
Meadow Jumping Mouse - <u>Zapus hudsonius</u>					X	X	X	X						X									
Snowshoe Hare - <u>Lepus americanus</u>		X	X					X						X									

SPECIES	HABITAT PREFERENCE AND RESTRICTIONS: Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	PRESENT POPULATION LEVELS: Abundant or Common	Uncommon	Occasional	Rare	Rare or Endangered	EFFECT OF PROJECT ACTION: Highly Detrimental	Moderately Detrimental	Slightly Detrimental	Present Status or No Apparent Impact	Slightly Advantageous	Moderately Advantageous	Highly Advantageous
Whitetail Jackrabbit - Lepus townsendi					X	X	X							X									
Eastern Cottontail - Sylvilagus floridanus		X						X	X			X											
Mule Deer - Odocoileus hemionus								X	X	X	X			X									
Whitetail Deer - Odocoileus virginianus			X					X	X			X											

APPENDIX D

BIRDS POSSIBLY OCCURRING IN THE BIG STONE LAKE WATERSHED

BIRDS POSSIBLY OCCURRING IN THE BIG STONE LAKE WATERSHED

SPECIES	RESIDENT STATUS				HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS						
	Permanent	Summer	Winter	Transient	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
Common Loon Gavia immer[a/]		X			X													X				
Red-Throated Loon Gavia stellata[a,b/]				X	X													X				
Red-Necked Grebe Podiceps grisegena[b/]				X	X												X					
Horned Grebe Podiceps auritus				X	X													X				
Pied-Billed Grebe Podilymbus podiceps		X			X												X					
White Pelican Pelecanus erythrorhynchos[b/]				X	X												X					
Double-Crested Cormorant Phalacrocorax auritus[b/]		X			X													X				
Whistling Swan Olor columbianus				X	X												X					
Canada Goose Branta canadensis		X			X	X		X			X								X	X		
White-Fronted Goose Anser albifrons[a/]				X	X	X		X			X							X		X		

SPECIES	RESIDENT STATUS				HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS						
	Permanent	Summer	Winter	Transient	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
Blue Goose Chen caerulescens				X	X	X		X			X								X	X		
Snow Goose Chen hyperborea				X	X	X		X			X							X		X		
Mallard Anas platyrhynchos		X			X	X													X	X	X	X
Pintail Anas acuta		X			X	X												X		X		X
Gadwall Anas strepera				X	X	X											X			X		X
American Widgeon Mareca americana				X	X	X		X			X							X		X		X
Shoveler Spatula clypeata		X			X	X													X	X		X
Blue-Winged Teal Anas discors		X			X	X												X		X		X
Green-Winged Teal Anas carolinensis		X			X													X		X		X
Wood Duck Aix sponsa[a]		X			X								X					X		X	X	

SPECIES	RESIDENCY STATUS				HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS						
	Permanent	Summer	Winter	Transient	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
Redhead Aythya americana		X			X	X												X		X		
Canvasback Aythya valisineria				X	X	X												X		X		
Ring-Necked Duck Aythya collaris		X			X													X		X		
Greater Scaup Aythya marila				X	X												X			X		
Lesser Scaup Aythya affinis		X			X	X													X	X	X	X
Common Goldeneye Bucephala clangula			X		X													X		X		
Bufflehead Bucephala albeola				X	X													X		X		
White-Winged Scoter Melanitta deglandi[a]				X	X														X	X		
Ruddy Duck Oxyura jamaicensis				X	X													X		X		
Common Merganser Mergus merganser				X	X													X		X	X	

SPECIES	RESIDENT STATUS: Permanent	Summer	Winter	Transient	HABITAT PREFERENCE AND RESTRICTIONS: Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	PRESENT POPULATION LEVELS: Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
Red-Breasted Merganser _Mergus serrator_				X	X													X		X		
Hooded Merganser _Lophodytes cucullatus_		X			X												X			X		
Turkey Vulture _Cathartus aura_		X						X	X	X	X	X						X				
Goshawk _Accipiter gentilis_		X												X	X		X				X	
Cooper's Hawk _Accipiter cooperii_ b/		X										X	X				X					
Sharp-Shinned Hawk _Accipiter striatus_		X										X	X					X				
Marsh Hawk _Circus cyaneus_		X				X			X	X	X							X				X
Rough-Legged Hawk _Buteo lagopus_			X					X	X	X	X						X					
Red-Tailed Hawk _Buteo jamaicensis_		X						X	X	X	X	X	X					X				
Red-Shouldered Hawk _Buteo lineatus_ a,b/		X						X			X	X						X				

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Swainson's Hawk[a/] <u>Buteo</u> <u>swainsoni</u>		X							X	X	X							X				X
Broad-Winged Hawk <u>Buteo</u> <u>platypterus</u>		X										X	X					X				
Golden Eagle <u>Aquila</u> <u>chrysaetos</u>[a/]			X						X	X					X	X						
Bald Eagle <u>Haliacetus</u> <u>leucocephalus</u>[a,d/]			X		X	X										X						
Osprey <u>Pandion</u> <u>haliaetus</u>[b,e/]				X	X	X											X					
Peregrine Falcon <u>Falco</u> <u>peregrinus</u>[a,d/]				X									X	X	X	X						
Pigeon Hawk <u>Falco</u> <u>columbarius</u>[a,e/]				X				X	X	X	X	X					X					
Sparrow Hawk <u>Falco</u> <u>sparrerius</u>[b/]		X						X	X	X	X	X						X			X	
Wild Turkey <u>Meleagris</u> <u>gallopavo</u>[a/]	X												X				X			X	X	
Ruffed Grouse <u>Bonasa</u> <u>umbellus</u>[a/]	X											X		X	X		X			X	X	

SPECIES	RESIDENT STATUS: Permanent	Summer	Winter	Transient	HABITAT PREFERENCE AND RESTRICTIONS: Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	PRESENT POPULATION LEVELS: Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
Sharp-Tailed Grouse Pedioecetes phasianellus[a,c]			X						X	X	X	X					X			X		X
Greater Prairie Chicken Tympanuchus cupido[a,d]	X								X							X				X	X	
Bobwhite Colinus virginiana[a]	X							X	X		X	X						X		X		
Ring-Necked Pheasant Phasianus colchicus	X							X	X		X	X						X		X	X	X
Gray Partridge Perdix perdix[a]	X							X	X		X							X		X	X	
Common Egret Casmerodius albus[a]		X			X	X												X				
Great Blue Heron Ardea herodias			X		X	X												X				
Green Heron Butorides virescens[a]		X			X	X												X				
Black-Crowned Night Heron Nycticorax nycticorax[a,b]		X				X	X											X				
American Bittern Botaurus lentiginosus		X				X												X				

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Least Bittern <u>Ixobrychus exilis</u>[a/]		X				X												X				
Sandhill Crane <u>Grus canadensis</u>		X				X		X	X								X					
Virginia Rail <u>Rallus limicola</u>		X				X	X											X		X		
Sora <u>Porzana carolina</u>		X				X	X											X		X		X
Yellow Rail <u>Coturnicops noveboracensis</u>[a/]				X		X	X	X	X							X						
King Rail <u>Rallus longirostris</u>[c/]		X				X	X											X		X		
Common Gallinule <u>Gallinula chloropus</u>[a/]		X			X	X												X		X		
American Coot <u>Fulica americana</u>		X				X												X		X		X
American Avocet <u>Recurvirostris americana</u>[a/]				X	X	X												X				
American Golden Plover <u>Pluvialis dominica</u>				X		X		X	X		X							X				

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Black-Bellied Plover _Squatarola squatarola_				X		X		X	X		X							X				
Piping Plover _Charadrius melodus_				X		X											X					
Semipalmated Plover _Charadrius semipalmatus_				X		X												X				
Killdeer _Charadrius vociferus_		X							X		X								X			X
Hudsonian Godwit _Limosa haemastica_ a/				X		X											X					
Upland Plover _Bartramia longicauda_		X				X				X							X					X
Buff-Breasted Sandpiper _Tryngites subruficollis_ a/				X						X							X					
Solitary Sandpiper _Tringa solitaria_				X		X	X											X				
Spotted Sandpiper _Actitis macularia_		X				X												X				
Willet _Catoptrophorus semipalmatus_		X				X												X				X

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Greater Yellowlegs _Totanus melanoleucus_				X		X												X				
Lesser Yellowlegs _Totanus flavipes_				X		X												X				
Stilt Sandpiper _Micropalama himantopus_				X		X											X					
Short-Billed Dowitcher _Limnodromus griseus_[c/]				X		X												X				
Long-Billed Dowitcher _Limnodromus scolopaceus_				X		X												X				
Ruddy Turnstone _Arenaria interpres_[a/]				X		X												X				
Pectoral Sandpiper _Erolia melanotos_				X		X											X					
Dunlin _Erolia alpina_[a/]				X		X												X				
Sanderling _Crocethia alba_				X		X												X				
White-Rumped Sandpiper _Erolia fuscicollis_				X		X											X					

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Baird's Sandpiper <u>Erolia</u> <u>bairdii</u>				X		X											X					
Least Sandpiper <u>Erolia</u> <u>minutilla</u>				X		X													X			
Semipalmated Sandpiper <u>Ereunetes</u> <u>pusillus</u>				X		X													X			
Western Sandpiper <u>Ereunetes</u> <u>mauri</u>				X		X												X				
Wilson's Phalarope <u>Steganopus</u> <u>tricolor</u>[a/]				X		X											X					X
American Woodcock <u>Philohela</u> <u>minor</u>[a/]		X					X						X					X		X		
Common Snipe <u>Capella</u> <u>gallinago</u>		X				X	X											X		X		
Herring Gull <u>Larus</u> <u>argentatus</u>				X	X														X			
Ring-Billed Gull <u>Larus</u> <u>delawarensis</u>				X	X														X			
Franklin's Gull <u>Larus</u> <u>pipixean</u>[a,b/]				X	X													X				

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Bonaparte's Gull <u>Larus philadelphia</u>				X	X													X				
Common Tern <u>Sterna hirundo</u>		X			X	X													X			
Forster's Tern <u>Sterna forsteri</u>				X	X	X												X				
Caspian Tern <u>Hydroprogne caspia</u>				X	X	X												X				
Black Tern <u>Chlidonias niger</u>		X			X	X											X					
Rock Dove <u>Columba livia</u>	X							X	X	X	X	X	X		X			X	X			
Mourning Dove <u>Zenaidura macroura</u>	X							X	X	X	X	X	X	X	X			X	X	X	X	X
Yellow-Billed Cuckoo <u>Coccyzus minor</u>[a/]		X										X	X					X				
Black-Billed Cuckoo <u>Coccyzus americanus</u>		X										X	X					X				X
Screech Owl <u>Otus asio</u>	X										X	X	X					X			X	

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Great Horned Owl <u>Bubo virginianus</u>	X							X	X	X	X	X	X	X	X			X			X	
Long-Eared Owl <u>Asio otus</u>	X											X	X	X	X		X					
Short-Eared Owl <u>Asio flammeus</u>		X				X		X	X	X	X						X				X	
Barn Owl <u>Tyto alba</u>[a,b]	X					X		X	X	X	X	X	X				X					
Snowy Owl <u>Nyctea scandiaca</u>[a]			X									X					X				X	
Barred Owl <u>Strix varia</u>	X					X	X					X	X				X					
Boreal Owl <u>Aegolius funereus</u>[a]			X											X			X					
Saw-Whet Owl <u>Aegolius acadicus</u>	X												X	X	X			X				
Whip-Poor-Will <u>Caprimulgus vociferus</u>[a]		X						X	X	X	X	X	X					X				
Common Nighthawk <u>Chordeiles acutipennis</u>		X				X		X	X	X	X	X						X				X

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Chimney Swift *Chaetura pelagica*		X						X	X	X	X	X	X					X				
Ruby-Throated Hummingbird *Archilochas colubris*		X							X			X	X					X				
Belted Kingfisher *Megaceryle alcyon*	X					X												X				
Yellow-Shafted Flicker *Colaptes auratus*	X							X	X	X	X	X	X					X			X	X
Red-Shafted Flicker *Colaptes cafer*[a/]			X					X	X	X	X	X	X					X			X	
Pileated Woodpecker *Dryocopus pileatus*[a/]	X												X		X		X				X	
Red-Bellied Woodpecker *Centurus carolinus*[a/]	X											X	X	X	X			X			X	
Red-Headed Woodpecker *Melanerpes erythrocephalus*		X										X	X				X					
Yellow-Bellied Sapsucker *Sphyrapicus varius*		X										X	X					X				
Hairy Woodpecker *Dendrocopos villosus*	X												X		X		X				X	

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Downy Woodpecker *Dendrocopos pubescens*	X											X	X		X			X			X	
Eastern Kingbird *Tyrannus tyrannus*		X						X	X	X	X	X						X				X
Western Kingbird *Tyrannus verticalis*[a/]		X						X	X	X	X	X						X				X
Great Crested Flycatcher *Myiarchus crinitus*		X						X	X	X	X	X	X		X			X				
Eastern Phoebe *Sayornis phoebe*		X									X	X						X				
Yellow-Bellied Flycatcher *Empidonax flaviventris*				X										X			X					
Acadian Flycatcher *Empidonax virescens*		X											X					X				
Traill's Flycatcher *Empidonax traillii*		X					X		X	X		X						X				X
Least Flycatcher *Empidonax minimus*		X							X	X		X						X				
Eastern Wood Pewee *Contopus virens*		X											X		X			X				

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Olive-Sided Flycatcher <u>Nuttallornis borealis</u>				X										X	X		X					
Horned Lark <u>Eremophila alpestris</u>	X							X	X	X	X							X			X	X
Barn Swallow <u>Hirundo rustica</u>		X						X	X	X	X	X	X					X				X
Cliff Swallow <u>Petrochelidon pyrrhonota</u>		X						X	X	X	X	X	X				X					X
Tree Swallow <u>Iridoprocne bicolor</u>		X				X						X						X				X
Bank Swallow <u>Riparia riparia</u>		X				X											X					
Rough-Winged Swallow <u>Stelgidopteryx ruficollis</u>		X				X											X					
Purple Martin <u>Progne subis</u>		X										X					X					
Blue Jay <u>Cyanocitta cristata</u>	X													X	X			X			X	
Gray Jay <u>Perisoreus canadensis</u>[a/]			X											X			X					

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Black-Billed Magpie Pica pica[a/]			X					X	X	X	X	X						X				
Common Crow Corvus brachyrhynchos	X							X	X	X	X	X							X		X	
Black-Capped Chickadee Parus atricapillus	X											X	X					X			X	
Boreal Chickadee Parus hudsonicus[a/]			X											X			X				X	
Tufted Titmouse Parus bicolor[a,c/]	X												X					X				
White-Breasted Nuthatch Sitta carolinensis	X												X					X			X	
Red-Breasted Nuthatch Sitta canadensis			X											X				X			X	
Brown Creeper Certhia familiaris		X												X				X			X	
House Wren Troglodytes aedon		X										X						X				
Winter Wren Troglodytes troglodytes[c/]				X									X				X					

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Bewick's Wren Thryomanes bewickii[a,b]		X							X			X						X				
Carolina Wren Thryothorus ludovicianus[a]	X											X						X				
Long-Billed Marsh Wren Telmatodytes palustris		X				X											X					X
Short-Billed Marsh Wren Cistothorus platensis		X				X											X					
Mockingbird Mimus polyglottos[a]			X					X	X	X	X	X						X				
Catbird Dumetella carolinensis		X										X						X				X
Brown Thrasher Toxostoma rufum		X										X						X				X
Robin Turdus migratorius	X								X	X		X	X					X			X	
Wood Thrush Hylocichla mustelina[a]		X										X	X					X				
Hermit Thrush Hylocichla guttata				X								X						X				

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Swainson's Thrush <u>Hylocichla</u> <u>ustulata</u>				X										X	X			X				
Gray-Cheeked Thrush <u>Hylocichla</u> <u>minima</u>				X										X	X		X					
Veery <u>Hylocicha</u> <u>fuscenscens</u>		X				X						X	X					X				
Eastern Bluebird <u>Sialia</u> <u>sialis</u>		X										X	X					X				
Blue-Gray Gnatcatcher <u>Polioptila</u> <u>caerulea</u>[a/]		X											X					X				
Golden-Crowned Kinglet <u>Regulus</u> <u>satrapa</u>				X										X	X			X			X	
Ruby-Crowned Kinglet <u>Regulus</u> <u>calendula</u>				X										X	X			X				
Water Pipit <u>Anthus</u> <u>spinoletta</u>				X		X			X	X	X							X				
Sprague's Pipit <u>Anthus</u> <u>spragueii</u>[a/]				X		X			X	X	X						X					
Bohemian Waxwing <u>Bombycilla</u> <u>garrulus</u>[a/]			X									X	X					X			X	

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Cedar Waxwing Bombycilla cedrorum	X											X	X					X			X	
Northern Shrike Lanius excubitor			X									X					X				X	
Loggerhead Shrike Lanius ludovicianus		X										X					X					
Starling Sturnus vulgaris	X							X	X	X	X	X							X		X	
Solitary vireo Vireo solitarius				X										X	X			X				
Bell's Vireo Vireo bellii a,b/		X							X			X						X				
Yellow-Throated Vireo Vireo flavifrons a/		X				X			X	X	X	X	X				X					
Red-Eyed Vireo Vireo olivaceus		X											X					X				
Philadelphia Vireo Vireo philadelphicus				X								X	X				X					
Warbling Vireo Vireo gilvus		X											X					X				

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Black-And-White Warbler *Mniotilta varia*		X											X					X				
Prothonotary Warbler *Protonotaria citraga*[a/]		X				X	X					X						X				
Golden-Winged Warbler *Vermivora chrysoptera*[a/]		X							X			X	X				X					
Blue-Winged Warbler *Vermivora pinus*[a/]				X					X			X					X					
Tennessee Warbler *Vermivora peregrina*				X										X	X			X				
Orange-Crowned Warbler *Vermivora celata*				X								X	X					X				
Nashville Warbler *Vermivora ruficapilla*		X											X					X				
Parula Warbler *Parula americana*[a/]		X											X	X	X			X				
Yellow Warbler *Dendroica petechia*		X										X						X				X
Magnolia Warbler *Dendroica magnolia*				X										X	X			X				

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	Permanent	Summer	Winter	Transient	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
Cape May Warbler _Dendroica_ _tigrina_[a/]				X										X			X					
Myrtle Warbler _Dendroica_ _coronata_		X												X					X			
Black-Throated Green Warbler _Dendroica_ _virens_		X											X	X	X			X				
Black-Throated Blue Warbler _Dendroica_ _caerulescens_[a/]				X										X				X				
Cerulean Warbler _Dendroica_ _cerulea_[a/]		X				X						X	X				X					
Blackburnian Warbler _Dendroica_ _fusca_[a/]				X									X	X	X			X				
Chestnut-Sided Warbler _Dendroica_ _pensylvanica_		X										X	X					X				
Bay-Breasted Warbler _Dendroica_ _castanea_				X										X			X					
Blackpoll Warbler _Dendroica_ _striata_				X										X					X			
Pine Warbler _Dendroica_ _pinus_[a/]		X											X	X	X			X				

SPECIES	RESIDENT STATUS: Permanent	Summer	Winter	Transient	HABITAT PREFERENCE AND RESTRICTIONS: Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	PRESENT POPULATION LEVELS: Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
Palm Warbler <u>Dendroica</u> <u>palmarum</u>				X					X		X	X					X					
Ovenbird <u>Seiurus</u> <u>aurocapillus</u>		X											X					X				
Northern Waterthrush <u>Seiurus</u> <u>noveboracensis</u>				X		X								X				X				
Louisiana Waterthrush <u>Seiurus</u> <u>motacilla</u>[a]		X				X	X										X					
Yellowthroat <u>Geothlypis</u> <u>trichas</u>[c]		X							X		X	X						X				X
Yellow-Breasted Chat <u>Icteria</u> <u>virens</u>[a]		X										X	X				X					
Mourning Warbler <u>Oporonis</u> <u>philadelphia</u>				X								X	X				X					
Connecticut Warbler <u>Oporonis</u> <u>agilis</u>[a]				X									X				X					
Wilson's Warbler <u>Wilsonia</u> <u>pusilla</u>				X								X					X					
Canada Warbler <u>Wilsonia</u> <u>canadensis</u>[a]				X										X	X			X				

SPECIES	RESIDENT STATUS: Permanent	Summer	Winter	Transient	HABITAT PREFERENCE AND RESTRICTIONS: Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	PRESENT POPULATION LEVELS: Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
American Redstart _Setophaga ruticilla_		X										X	X					X				
House Sparrow _Passer domesticus_	X							X	X		X	X							X		X	
Bobolink _Dolichonyx oryzivorus_		X							X		X	X					X					X
Eastern Meadowlark _Sturnella magna_		X						X	X	X	X	X						X				
Western Meadowlark _Sturnella neglecta_		X						X	X	X	X	X						X			X	X
Yellow-Headed Blackbird _Xanthocephalus xanthocephalus_		X				X												X				X
Red-Winged Blackbird _Agelaius phoeniceus_		X				X		X	X		X	X							X		X	X
Rusty Blackbird _Euphagus carolinus_				X			X										X				X	
Brewer's Blackbird _Euphagus cyanocephalus_		X						X	X		X	X						X			X	X
Common Grackle _Quiscalus quiscula_		X						X	X		X	X							X		X	X

	RESIDENT STATUS				HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS						
SPECIES	Permanent	Summer	Winter	Transient	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
Brown-Headed Cowbird Molothrus ater		X						X	X		X	X						X			X	X
Orchard Oriole Icterus spurius[a]		X										X					X					
Baltimore Oriole Icterus galbula		X										X	X					X				X
Scarlet Tanager Piranga olivacea		X											X	X	X			X				
Cardinal Richmondena cardinalis[a]	X											X						X			X	
Rose-Breasted Grosbeak Pheucticus ludivicianus[a]		X											X					X				
Evening Grosbeak Hesperiphona vespertina			X											X					X		X	
Indigo Bunting Passerina cyanea[a]		X										X						X				
Purple Finch Carpodacus purpureus		X											X					X			X	
Pine Grosbeak Pinicola enucleator			X											X			X				X	

SPECIES	RESIDENT STATUS				HABITAT PREFERENCE AND RESTRICTIONS											PRESENT POPULATION LEVELS						
	Permanent	Summer	Winter	Transient	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
Common Redpoll Acanthis flammea			X					X	X		X						X				X	
Pine Siskin Spinus pinus			X											X	X		X				X	
American Goldfinch Spinus tristis	X							X	X	·	X	X	X					X			X	X
Red Crossbill Loxia curvirostra[a/]	X													X	X			X			X	
Dickcissel Spiza americana[a/]		X						X	X	X	X								X			X
Rufous-Sided Towhee Pipilo erythrophthalmus		X										X						X				
Savannah Sparrow Passerculus sandwichensis		X						X	X	X	X							X				X
Grasshopper Sparrow Ammodramus savannarum		X						X	X		X							X				X
Henslow's Sparrow Passerherbulus henslowii[a,c/]		X				X										X						
LeConte's Sparrow Passerherbulus caudacutus		X				X												X				

SPECIES	RESIDENT STATUS				HABITAT PREFERENCE AND RESTRICTIONS											POPULATION LEVELS						
	Permanent	Summer	Winter	Transient	Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
Sharp-Tailed Sparrow _Ammospiza caudacuta_				X		X												X				
Vesper Sparrow _Pooecetes gramineus_		X						X	X	X	X						X					X
Lark Sparrow _Chondestes grammacus_		X						X	X		X	X					X					
Oregon Junco _Junco oreganus_[a/]			X					X	X	X	X	X		X	X			X			X	
Slate-Colored Junco _Junco hyemalis_			X						X		X	X		X					X		X	
Tree Sparrow _Spizella arborea_			X					X	X		X	X						X			X	
Chipping Sparrow _Spizella passerina_		X						X	X		X	X						X				X
Clay-Colored Sparrow _Spizella pallida_[a/]		X									X	X					X					X
Field Sparrow _Spizella pusilla_[a/]		X						X	X		X	X						X				
Harris Sparrow _Zonotrichia querula_[a/]				X								X					X				X	

SPECIES	RESIDENT STATUS: Permanent	Summer	Winter	Transient	HABITAT PREFERENCE AND RESTRICTIONS: Aquatic	Marsh	Swamp	Cropland	Pasture	Prairie	Old Fields	Forest Edge	Deciduous Forest	Coniferous Forest	Mixed Forest	PRESENT POPULATION LEVELS: Rare or Endangered	Normally Low	Moderate	High	Game Species	Christmas Count Species	Breeding Bird Count Species
White-Crowned Sparrow Zonotrichia leucophrys				X					X		X	X						X				
White-Throated Sparrow Zonotrichia albicollis				X								X							X			
Fox Sparrow Passerella iliaca				X								X	X	X	X			X				
Lincoln's Sparrow Melospiza lincolnii				X		X						X					X					
Swamp Sparrow Melospiza georgiana		X				X			X		X							X				
Song Sparrow Melospiza melodia		X				X						X						X			X	X
Chestnut-Collared Longspur Calcarius ornatus[a]				X					X	X	X							X				X
Lapland Longspur Calcarius lapponicus			X						X	X	X							X			X	
Smith's Longspur Calcarius pictus[a]				X					X	X	X						X					
Snow Bunting Plectrophenax nivalis[a]			X							X	X							X			X	

a/ Birds that are in the periphery of their range in the Big Stone Lake Watershed.[24]
b/ Birds that are on the Blue List for 1974.[25]
c/ Status undetermined or candidate species for the Blue List in 1974.[25]
d/ Birds that are considered threatened or endangered by the Fish and Wildlife Service.[23]
e/ Status undetermined by the Fish and Wildlife Service.[23]

APPENDIX E

SPECIES OF AQUATIC PLANTS POSSIBLY OCCURRING IN THE BIG STONE LAKE REGION

SPECIES OF AQUATIC PLANTS POSSIBLY OCCURRING IN THE BIG STONE LAKE REGION

Common Cattail	*Typha latifolia*
Leafy Pondweed	*Potamogeton foliosus*
Sago Pondweed	*P. pectinatus*
Richardson Pondweed	*P. richardsonii*
Flatstem Pondweed	*P. zosteriformis*
Widgeongrass	*Ruppia occidentalis*
Horned Pondweed	*Zannichellia palustris*
Slender Naiad	*Najas flexilis*
Spiny Naiad	*N. marina*
Broadleaf Waterplantain	*Alisma plantago-aquatica*
Northern Arrowhead	*Sagittaria cuneata*
Waterweed	*Anacharis occidentalis*
Eel Grass	*Vallisneria americana*
Reed Grass	*Phragmites communis*
Wild Rice	*Zizania aquatica*
Slender Spikerush	*Eleocharis acicularis*
Common Spikerush	*E. palustris*
Hardstem Bulrush	*Scirpus acutus*
Three-Square	*S. americanus*
River Bulrush	*S. fluviatilis*
Slender Bulrush	*S. heterochaetus*
Alkali Bulrush	*S. paludosus*
Sweetflag	*Acorus calamus*
Star Duckweed	*Lemna trisulca*
Giant Duckweed	*Spirodela polyrhiza*
Water Stargrass	*Heteranthera dubia*
Water Smartweed	*Polygonum natans*
Coontail	*Ceratophyllum demersum*
Northern Water Milfoil	*Myriophyllum exalbescens*
Common Bladderwort	*Utricularia vulgaris*

Source: Moyle, John B., "Some Chemical Factors Influencing the Distribution of Aquatic Plants in Minnesota," Amer. Midl. Nat., **34** (2): 402-420 (1945).

APPENDIX F

FISHES WHOSE GEOGRAPHIC RANGE INCLUDED THE BIG STONE LAKE REGION BUT HAVE NOT BEEN COLLECTED IN THE PROJECT AREA

FISHES WHOSE GEOGRAPHIC RANGE INCLUDED THE BIG STONE LAKE REGION BUT HAVE NOT BEEN COLLECTED IN THE PROJECT AREA

Chestnut Lamprey[a]	*Ichthyomyzon castaneus*
Silver Lamprey	*I. unicuspis*
Lake Sturgeon[a]	*Acipenser fulvescens*
Longnose Gar	*Lepisosteus osseus*
American Eel	*Anquilla rostrata*
Rainbow Trout	*Salmo gairdneri*
Goldeye	*Hiodon alosoides*
Mooneye[a]	*H. tergisus*
Central Mudminnow	*Umbra limi*
Northern Redbelly Dace	*Chrosomus eos*
Silvery Minnow	*Hybognathus nuchalis*
Silver Club	*Hybopsis storeriana*
Golden Shiner	*Notemigonus crysoleucas*
River Shiner	*Notropis blennius*
Blackchin Shiner	*N. heterodon*
Blacknose Shiner	*N. heterolepis*
Spotfin Shiner[a]	*N. spilopterus*
Longnose Dace	*Rhinichthys cataractae*
Longnose Sucker	*Catostomus catostomus*
Northern Hogsucker	*Hypentelium nigricans*
Silver Redhorse[a]	*Moxostoma anisurum*
River Redhorse	*M. carinatum*
Black Redhorse	*M. duquesnei*
Greater Redhorse[a]	*M. valenciennesi*
Channel Catfish	*Ictalurus punctatus*
Banded Killifish	*Fundulus diaphanus*
Burbot	*Lota lota*
Trout-Perch	*Percopsis omiscomaycus*
Green Sunfish	*Lepomis cyanellus*
Longear Sunfish[a]	*Lepomis megalotis*
Smallmouth Bass	*Micropterus dolomieui*
Sauger	*Stizostedion canadense*
Rainbow Darter[a]	*Etheostoma caeruleum*
Fantail Darter[a]	*E. flabellare*
Least Darter	*E. microperca*
Logperch	*Percina caprodes*
River Darter[a]	*P. shumardi*
Slimy Sculpin	*Cottus cognatus*

a/According to Bailey and Allum these species should be carefully searched for in the Big Stone Lake area. Some have been reported but they have not been officially identified.

Sources: Scott, W. B., and E. J. Crossman, *Freshwater Fishes of Canada*., Fish Res. Bd. of Canada Bull., pp. 184-966, Ottawa (1973).
Bailey, R. M., and M. O. Allum, *Fishes of South Dakota*, Mus. Zool., Univ. Mich. Misc. Publ. 119:1-131, pl. 1, June 5, 1962.

Nomenclature in accordance with Bailey, R. M., et al. *A List of Common and Scientific Names of Fishes from the United States and Canada*, Third edition, Amer. Fish. Soc. Spec. Publ. No. 6, Washington, D.C. (1970).

APPENDIX G

SOUTH DAKOTA BOARD OF ENVIRONMENTAL PROTECTION
WATER POLLUTION

SOUTH DAKOTA BOARD OF ENVIRONMENTAL PROTECTION
WATER POLLUTION

Lakes	Classification	Location
Big Stone	4,10	Roberts County
Rivers		
Whetstone	5,8	from the South Dakota-Minnesota border to the headwaters of its North Fork.
Whetstone	6,8	South Fork, Grant County
Little Minnesota	5,8	Roberts County
Substation Creek	3,8	from the North Fork of the Whetstone River to its headwaters.

LAKE AND STREAM CLASSIFICATIONS

1. Domestic water supplies waters;
2. Cold-water permanent fish life propagation waters;
3. Cold-water marginal fish life propagation waters;
4. Warm-water permanent fish life propagation waters;
5. Warm-water semipermanent fish life propagation waters;
6. Warm-water marginal fish life propagation waters;
7. Immersion recreation waters;
8. Limited contact recreation waters;
9. Stock watering and wildlife propagation waters;
10. Irrigation waters.

The waters of Big Stone Lake are classified as warm-water permanent fish life propagation waters. The criteria of parameters for this classification are as follows:

1. Total chlorine residual shall not exceed 0.02 mg/liter at any time;

2. Ammonia nitrogen shall not exceed 1.0 mg/liter (as N) at any time;

3. Total cyanide shall not exceed 0.02 mg/liter at any time;

4. Free cyanide shall not exceed 0.005 mg/liter at any time;

5. Dissolved oxygen shall be greater than 5.0 mg/liter at all times, except during April and May, when dissolved oxygen shall be greater than 6.0 mg/liter;

6. Undisassociated hydrogen sulfide shall not exceed 0.002 mg/liter at any time;

7. The average total iron concentration shall not exceed 0.2 mg/liter during a 24-hr period, in addition, the numerical value of any one sample collected during the period shall not exceed 0.35 mg/liter (1.75 times the allowable maximum);

8. The pH shall be greater than 6.5 units and less than 9.0 units at all times;

9. The average suspended solids shall not exceed 90 mg/liter over a 5-day period, in addition, the numerical value of any one sample collected during the period shall not exceed 180 mg/liter (2.0 times the allowable maximum);

10. Temperature shall not exceed 80°F at any time;

11. The average turbidity shall not exceed 50 JTU over a 5-day period, in addition, the numerical value of any one sample collected during the period shall not exceed 100 JTU (2.0 times the allowable maximum).

The waters of Big Stone Lake may also be utilized as:

1. Immersion recreation waters, which requires that the number of fecal coliform organisms not exceed 200 MPN/100 ml and coliform organisms not exceed 1,000 MPN/100 ml;

2. Limited contact recreation waters;

3. Stock watering and wildlife propagation waters;

4. Irrigation waters.

The waters of the Little Minnesota River, the Whetstone River and its North Fork are classified as warm-water semipermanent fish life propagation waters. The criteria of parameters for this classification are as follows:

1. Total chlorine residual shall not exceed 0.02 mg/liter at any time;

2. Ammonia nitrogen shall not exceed 1.0 mg/liter (as N) at any time;

3. Total cyanide shall not exceed 0.02 mg/liter at any time;

4. Free cyanide shall not exceed 0.005 mg/liter at any time;

5. Dissolved oxygen shall be greater than 5.0 mg/liter at all times;

6. Undisassociated hydrogen sulfide shall not exceed 0.002 mg/liter at any time;

7. The average iron concentration shall not exceed 0.02 mg/liter during a 24-hr period, in addition, the numerical value of any one sample collected during the period shall not exceed 0.35 mg/liter (1.75 times the allowable maximum);

8. The pH shall be greater than 6.3 units and less than 9.0 units at all times;

9. The average suspended solids shall not exceed 90 mg/liter over a 5-day period, in addition, the numerical value of any one sample collected during the period shall not exceed 180 mg/liter (2.0 times the allowable maximum);

10. Temperature shall not exceed 90°F at any time;

11. The average turbidity shall not exceed 50 JTU over a 5-day period, in addition, the numerical value of any one sample shall not exceed 100 JTU (2.0 times the allowable maximum).

The waters of these rivers may also be utilized as:

1. Limited contact recreation waters which requires that the number of fecal coliform organisms not exceed 1,000 MPN/100 ml;

2. Stock watering and wildlife propagation waters;

3. Irrigation waters.

The waters of the South Fork of the Whetstone River are classified as warm-water marginal fish life propagation waters. The criteria of parameters for this classification are as follows:

1. Total chlorine residual shall not exceed 0.02 mg/liter at any time;

2. Ammonia nitrogen shall not exceed 1.5 mg/liter (as N) at any time;

3. Total cyanide shall not exceed 0.02 mg/liter at any time;

4. Free cyanide shall not exceed 0.005 mg/liter at any time;

5. Dissolved oxygen shall be greater than 5.0 mg/liter at all times;

6. Undisassociated hydrogen sulfide shall not exceed 0.002 mg/liter at any time;

7. The average iron concentration shall not exceed 0.2 mg/liter during a 24-hr period, in addition, the numerical value of any one sample collected during the period shall not exceed 0.35 mg/liter (1.75 times the allowable maximum);

8. The pH shall be greater than 6.0 units and less than 9.0 units at all times.

9. The average suspended solids shall not exceed 90 mg/liter over a 5-day period, in addition, the numerical value of any one sample collected during the period shall not exceed 180 mg/liter (2.0 times the allowable maximum);

10. Temperature shall not exceed 90°F at any time;

11. The average turbidity shall not exceed 50 JTU over a 5-day period, in addition, the numerical value of any one sample collected during the period shall not exceed 100 JTU (2.0 times the allowable maximum).

The waters of this river may also be utilized as:

1. Limited contact recreation waters;

2. Stock watering and wildlife propagation waters;

3. Irrigation waters.

The waters of Substation Creek are classified as cold-water marginal fish life propagation waters. The criteria of parameters for this classification are as follows:

1. Total chlorine residual shall not exceed 0.02 mg/liter at any time;

2. Ammonia nitrogen shall not exceed 1.0 mg/liter at any time;

3. Total cyanide shall not exceed 0.02 mg/liter at any time;

4. Free cyanide shall not exceed 0.005 mg/liter at any time;

5. Dissolved oxygen shall be greater than 5.0 mg/liter at all times;

6. Undisassociated hydrogen sulfide shall not exceed 0.002 mg/liter at any time;

7. The average iron concentration shall not exceed 0.2 mg/liter during a 24-hr period, in addition, the numerical value of any one sample collected during the period shall not exceed 0.35 mg/liter (1.75 times the allowable maximum);

8. The pH shall be greater than 6.5 units and less than 8.8 units at all times;

9. The average suspended solids shall not exceed 90 mg/liter over a 5-day period, in addition, the numerical value of any one sample collected during the period shall not exceed 180 mg/liter (2.0 times the allowable maximum);

10. Temperature shall not exceed 75°F at any time;

11. The average turbidity shall not exceed 50 JTU over a 5-day period, in addition, the numerical value of any one sample collected during the period shall not exceed 100 JTU (2.0 times the allowable maximum).

The waters of Substation Creek may also be utilized as:

1. Limited contact recreation waters;

2. Stock watering and wildlife propagation waters;

3. Irrigation waters.

The following general criteria also apply to the lake and streams mentioned above:

1. No discharge shall affect the temperature by more than 4°F in Substation Creek; by more than 5°F in the Little Minnesota, the Whetstone River, and the South Fork of the Whetstone River; or by more than 3°F in Big Stone Lake. In addition, the maximum temperature change shall not exceed 2°F per hr.

2. No material can be discharged which would change the pH of the receiving waters by more than 0.5 pH unit.

3. No materials can be discharged which would cause undesirable tastes, undesirable odors, or offensive visual effects in receiving waters.

4. The concentration of petroleum-derived materials discharged into any lake or stream cannot exceed 10 mg/liter or impart a visible film to the surface of the water.

5. No toxic materials can be discharged in concentrations in excess of 0.1 times the median tolerance limit for short residual compounds or 0.01 times the median tolerance limit for accumulative substances. The residual life of a substance may not exceed 30 days.

6. The average dissolved concentrations (including naturally-occurring concentrations) of the following radioactive material cannot be exceeded:

Iodine 131	5 PCi/ℓ
Radium 226	1 PCi/ℓ
Strontium 89	100 PCi/ℓ
Strontium 90	10 PCi/ℓ
Tritium	300 PCi/ℓ

Source: South Dakota Rules of the Board of Environmental Protection, Water Pollution Program, Article 34:04.

APPENDIX H

MINNESOTA POLLUTION AGENCY, 1973 SUPPLEMENT

RULES AND REGULATIONS (WPC 25)

Waters	Reach or Area Involved or Location	Classification
Lakes		
Salt Lake	(T. 117; R. 46)	2B, 3B
South Silver Lake	(T. 101; R. 30)	2B, 3B
Big Stone Lake	(T. 121, 122, 123, 124; R. 46, 47, 48, 49)	2B, 3B
Rivers		
Minnesota River	Big Stone Lake outlet to Granite Falls	1C, 2B, 3B
Minnesota River	Granite Falls to Mankato	2B, 3B
Minnesota River	Mankato to Carver Rapids	2B, 3B
Minnesota River	Carver Rapids to mouth	2C, 3B
Little Minnesota River	South Dakota border crossing to Big Stone Lake	2C, 3B
Whetstone River	South Dakota border to mouth	2C, 3B
Streams		
Emily Creek	(T. 118, 119, R. 43)	2C
Fish Creek	(T. 123, 124, R. 47, 48)	2C
Five Mile Creek	(T. 120, R. 44)	2C
Stony Run	(T. 121, 122, R. 45, 46)	2C

CLASSIFICATION DEFINITIONS (WPC 15)

Water Use Classifications--All Interstate Waters of the State

Based on considerations of best usage in the interest of the public and in conformance with the requirements of the applicable statutes, the interstate waters of the state shall be grouped into one or more of the following classes:

1. Domestic Consumption: To include all interstate waters which are or may be used as a source of supply for drinking, culinary or food processing use or other domestic purposes, and for which quality control is or may be necessary to protect the public health, safety or welfare.

2. Fisheries and Recreation: To include all interstate waters which are or may be used for fishing, fish culture, bathing or any other recreational purposes, and for which quality control is or may be necessary to protect aquatic or terrestrial life, or the public health, safety or welfare.

3. Industrial Consumption: To include all interstate waters which are or may be used as a source of supply for industrial process or cooling water, or any other industrial or commercial purposes, and for which quality control is or may be necessary to protect the public health, safety or welfare.

4. Agriculture and Wildlife: To include all interstate waters which are or may be used for any agriculture purposes, including stock watering and irrigation, or by waterfowl or other wildlife, and for which quality control is or may be necessary to protect terrestrial life or the public health, safety or welfare.

5. Navigation and Waste Disposal: To include all interstate waters which are or may be used for any form of water transportation or navigation, disposal of sewage, industrial waste or other waste effluents, or fire prevention, and for which quality control is or may be necessary to protect the public health, safety or welfare.

6. Other Uses: To include interstate waters which are or may serve the above listed uses or any other beneficial uses not listed herein, including without limitation any such uses in this or any other state, province, or nation of any interstate waters flowing through or originating in this state, and for which quality control is or may be necessary for the above declared purposes, or to conform with the requirements of the legally constituted state or national agencies having jurisdiction over such interstate waters, or any other considerations the Agency may deem proper.

GENERAL STANDARDS APPLICABLE TO ALL INTERSTATE WATERS OF THE STATE (WPC 15)

1. No untreated sewage shall be discharged into any interstate waters of the state. No treated sewage, or industrial waste or other wastes containing viable pathogenic organisms, shall be discharged into interstate waters of the state without effective disinfection. Effective disinfection of any discharges, including combined flows of sewage and storm water, will be recharges, including combined flows of sewage and storm water, will be required where necessary to protect the specified uses of the interstate waters.

2. No sewage, industrial waste or other wastes shall be discharged into any interstate waters of the state so as to cause any nuisance conditions, such as the presence of significant amounts of floating solids, scum, oil slicks, excessive suspended solids, material discoloration, obnoxious odors, gas ebullition, deleterious sludge deposits, undesirable slimes or fungus growths, or other offensive or harmful effects.

3. Existing discharges of inadequately treated sewage, industrial waste or other wastes shall be abated, treated or controlled so as to comply with the applicable standards. Separation of sanitary sewage from natural run-off may be required where necessary to ensure continuous effective treatment of sewage.

4. The highest levels of water quality, including, but not limited to, dissolved oxygen, which are attainable in the interstate waters by continuous operation at their maximum capability of all primary and secondary units of treatment works or their equivalent discharging effluents into the interstate waters shall be maintained in order to enhance conditions for the specified uses.

5. Means for expediting mixing and dispersion of sewage, industrial waste, or other waste effluents in the receiving interstate waters are to be provided so far as practicable when deemed necessary by the Agency to maintain the quality of the receiving interstate waters in accordance with applicable standards. Mixing zones be established by the Agency on an individual basis, with primary consideration being given to the following guidelines: (a) mixing zones in rivers shall permit an acceptable passageway for the movement of fish; (b) the total mixing zone or zones at any transect of the stream should contain no more than 25% of the crossectional area and/or volume of flow of the stream, and should not extend over more than 50% of the width; (c) mixing zone characteristics shall not be lethal to aquatic organisms; (d) for contaminants other than heat, the 96 hour median tolerance limit for indigenous fish and fish food organisms should not be exceeded at any point in the mixing zone; (e) mixing zones should be as small as possible, and not intersect spawning or nursery areas, migratory routes, water intakes, nor mouths of rivers; and (f) overlapping of mixing zones should be minimized and measures taken to prevent adverse synergistic effects.

6. It is herein established that the Agency shall require secondary treatment as a minimum for all municipal sewage and biodegradable industrial or other wastes to meet the adopted water quality standards. A comparable high degree of treatment or its equivalent also shall be required of all nonbiodegradable industrial or other wastes unless the discharger can demonstrate to the Agency that a lesser degree of treatment or control will provide for water quality enhancement commensurate with

present and proposed future water uses and a variance is granted under the provisions of the variance clause. Secondary treatment facilities are defined as works which will provide effective sedimentation, biochemical oxidation, and disinfection, or the equivalent, including effluents conforming to the following:

Substance or Characteristic	Limiting Concentration or Range*
5-Day Biochemical Oxygen demand	25 mg/liter
Fecal coliform group organisms	200 most probable number/100 ml
Total suspended solids	30 mg/liter
Pathogenic organisms	None
Oil	Essentially free of visible oil
Phosphorus**	1 mg/liter
Turbidity	25
pH range	6.5 - 8.5
Unspecified toxic or corrosive substances	None at levels acutely toxic to humans or other animals or plant life, or directly damaging to real property.

In addition to providing secondary treatment as defined above, all dischargers of sewage, industrial wastes or other wastes also shall provide the best practicable control technology not later than July 1, 1977,

* The arithmetic mean for concentrations of 5-day biochemical oxygen demand and total suspended solids shall not exceed the stated values in a period of 30 consecutive days and 45 milligrams per liter in a period of 7 consecutive days. Disinfection of wastewater effluents to reduce the coliform organisms levels is required year around. The geometric mean for the fecal coliform organisms shall not exceea the stated value in a period of 30 consecutive days and 400 most probable number per 100 milliliters in a period of 7 consecutive days. The application of the coliform and pathogencc organism standards ordinarily shall be limited to sewage or other effluents containing admixtures of sewage and shall not apply to industrial wastes except where the presence of sewage, fecal coliform organisms or viable pathogenic organisms in such wastes is known or reasonably certain.

** Where the discharge of effluent is directly to or affects a lake or reservoir. Removal of nutrients from all wastes shall be provided to the fullest practicable extent wherever sources of nutrients are considered to be actually or potentially detrimental to preservation or enhancement of the designated water uses.

and best available technology economically achievable by July 1, 1983, and any other applicable treatment standards as defined by and in accordance with the requirements and schedules of the Federal Water Pollution Control Act, 33 U.S.C. 1251 et seq., as amended, and applicable regulations or rules promulgated pursuant thereto by the Administrator of the U.S. Environmental Protection Agency.

7. Dischargers of sewage, industrial waste or other waste effluents shall be controlled so that the water quality standards will be maintained at all stream flows which are equal to or exceeded by 90 percent of the seven consecutive daily average flows of record (the lowest weekly flow with a once in ten year recurrence interval) for the critical month(s). The period of record for determining the specific flow for the stated recurrence interval, where records are available, shall include at least the most recent ten years of record, including flow records obtained after establishment of flow regulation devices, if any. Such calculations shall not be applied to lakes and their embayments which have no comparable flow recurrence interval. Where stream flow records are not available, the flow may be estimated on the basis of available information on the watershed characteristics, precipitation, run-off and other relevant data.

Allowance shall not be made in the design of treatment works for low stream flow augmentation unless such flow augmentation of minimum flow is dependable and controlled under applicable laws or regulations.

8. In any instance where it is evident that the minimal treatment specified in Item 6 and dispersion are not effective in preventing pollution or if at the applicable flows it is evident that the specified stream flow is inadequate to protect the specified water quality standards, the specific standards may be interpreted as effluent standards for control purposes. In addition, the following effluent standards may be applied without any allowance for dilution where stream flow or other factors are such as to prevent adequate dilution, or where it is otherwise necessary to protect the interstate waters for the stated uses:

Item*	Limits
5 day biochemical oxygen demand	5 mg/liter
Total suspended solids	5 mg/liter

9. In any case where, after a public hearing, the Agency finds it necessary for conformance with Federal requirements, or conservation of the interstate waters of the state, or protection of the public health, or in furtherance of the development of the economic welfare of the state, it may prohibit or further limit the discharge to any designated interstate waters of any sewage, industrial waste, or other waste effluents, or any component thereof, whether such effluents are treated or untreated, or existing or new, notwithstanding any other provisions of classifications or specific standards stated herein which may be applicable to such designated interstate waters.

10. It shall be incumbent upon all persons responsible for existing or new sources of sewage, industrial wastes or other wastes which are or will be discharged to interstate waters, to treat or control their wastes so as to produce effluents having a common level or concentration of pollutants of comparable nature or effect as may be necessary to meet the specified standards or better, but this shall not be interpreted to prohibit the Agency after providing an opportunity for public hearing from accepting effective loss prevention and/or water conservation measures or process changes or other waste control measures or arrangements as being equivalent to the waste treatment measures required for compliance with applicable effluent and/or water quality standards or load allocations.

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* The concentrations specified in item 6 of this regulation may be used in lieu thereof if the discharge of effluent is restricted to the spring flush or other high runoff periods when the stream flow rate above the discharge point is sufficiently greater than the effluent flow rate to insure that the applicable water quality standards are met during such discharge point. If treatment works are designed and constructed to meet the specified limits given above for a continuous discharge, at the discretion of the Agency the operation of such works may allow for the effluent quality to vary between the limits specified above and in item 6, provided the water quality standards and all other requirements of the Agency and the U.S Environmental Protection Agency are being met. Such variability of operation must be based on adequate monitoring of the treatment works and the effluent and receiving waters as specified by the Agency.

11. All sources of sewage, industrial waste, or other waste which do not at present have a valid operation and discharge permit, or an application for the same pending before the Agency, shall apply for the same within 30 days of the adoption of this regulation, or the Agency may abate the source forthwith. The provisions of item 6 relating to effluent quality standards, and the other provisions of this regulation, are applicable to existing sewage, industrial waste or other waste disposal facilities and the effluent discharged therefrom. Nothing herein shall be construed to prevent the Agency subsequently from modifying any existing permits so as to conform with federal requirements and the requirements of this regulation.

12. Liquid substances which are not commonly considered to be sewage or industrial wastes but which could constitute a pollution hazard shall be stored in accordance with Regulation WPC 4, and any revisions or amendments thereto. Other wastes as defined by law or other substances which could constitute a pollution hazard shall not be deposited in any manner such that the same may be likely to gain entry into any interstate waters of the state in excess of or contrary to any of the standards herein adopted, or cause pollution as defined by law.

13. No sewage, industrial waste or other wastes shall be discharged into the interstate waters of the state in such quantity or in such manner alone or in combination with other substances as to cause pollution thereof as defined by law. In any case where the interstate waters of the state into which sewage, industrial wastes or other waste effluents discharge are assigned different standards than the interstate waters into which such receiving interstate waters flow, the standards applicable to the interstate waters into which such sewage, industrial waste or other wastes discharged shall be supplemented by the following:

The quality of any waters of the state receiving sewage, industrial waste or other waste effluents shall be such that no violation of the standards of any interstate waters of the state in any other class shall occur by reason of the discharge of such sewage, industrial waste or other waste effluents.

14. Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, of undefined toxicity to fish or other biota shall be resolved in accordance with the latest methods recommended by the U.S. Environmental Protection Agency. The recommendations of the National Technical Advisory Committee appointed by the U.S. Environmental Protection Agency shall be used as official guidelines in all aspects where the recommendations may be applicable. Toxic substances shall not exceed 1/10 of the 96 hour median tolerance limit (TLM) as a water quality standard except that other more stringent application factors shall be used when justified on the basis of available evidence.

15. All persons operating or responsible for sewage, industrial waste or other waste disposal systems which are adjacent to or which discharge effluents to these waters or to tributaries which affect the same, shall submit regularly every month a report to the agency on the operation of the disposal system, the effluent flow, and the characteristics of the effluents and receiving waters. Sufficient data on measurements, observations, sampling and analyses, and other pertinent information shall be furnished as may be required by the Agency to adequately evaluate the condition of the disposal system, the effluent, and the waters receiving or affected by the effluent.

SPECIFIC STANDARDS OF QUALITY AND PURITY FOR DESIGNATED CLASSES OF INTERSTATE WATERS OF THE STATE

The following standards shall prescribe the qualities or properties of the interstate waters of the state which are necessary for the designated public use or benefit and which, if the limiting conditions given are exceeded, shall be considered indicative of a polluted condition which is actually or potentially deleterious, harmful, detrimental or injurious with respect to such designated uses or established classes of the interstate waters:

Domestic Consumption

Class A: The quality of this class of the interstate waters of the state shall be such that without treatment of any kind the raw waters will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards--1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U.S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to underground waters with a high degree of natural protection. The basic requirements are given below:

Substance or Characteristic	Limit or Range
Total coliform organisms	1 most probable number/100 ml
Turbidity value	5
Color value	15
Threshold odor number	3
Methylene blue active substance (MBAS)	0.5 mg/liter

Substance or Characteristic	Limit or Range
Arsenic (As)	0.01 mg/liter
Chlorides (Cl)	250 mg/liter
Copper (Cu)	1 mg/liter
Carbon Chloroform extract	0.2 mg/liter
Cyanides (CN)	0.01 mg/liter
Fluorides (F)	1.5 mg/liter
Iron (Fe)	0.3 mg/liter
Manganese (Mn)	0.05 mg/liter
Nitrates (NO_3)	45 mg/liter
Phenol	0.001 mg/liter
Sulfates (SO_4)	250 mg/liter
Total dissolved solids	500 mg/liter
Zinc (Zn)	5 mg/liter
Barium (Ba)	1 mg/liter
Cadmium (Cd)	0.01 mg/liter
Chromium (Hexavalent, Cr)	0.05 mg/liter
Lead (Pb)	0.05 mg/liter
Selenium (Se)	0.01 mg/liter
Silver (Ag)	0.05 mg/liter
Radioactive material	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

<u>Class B</u>: The quality of this class of the interstate waters of the state shall be such that with approved disinfection, such as simple chlorination or its equivalent, the treated water will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards--1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U.S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface and underground waters with a moderately high degree of natural protection. The physical and chemical standards quoted above for Class A interstate waters shall also apply to these interstate waters in the untreated state, except as listed below:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	10 most probable number/100 ml

Class C: The quality of this class of the interstate waters of the state shall be such that with treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, or other equivalent treatment processes, the treated water will meet in all respects both the mandatory and recommended requirements of the Public Health Service Drinking Water Standards--1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U.S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface waters, and ground waters in aquifers not considered to afford adequate protection against contamination from surface or other sources of pollution. Such aquifers normally would include fractured and channeled limestone, unprotected impervious hard rock where interstate water is obtained from mechanical fractures, joints, etc., with surface connections, and coarse gravels subjected to surface water infiltration. The physical chemical standards quoted above for Class A interstate waters shall also apply to these interstate waters in the untreated state, except as listed below:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number/100 ml
Turbidity value	25

Class D: The quality of this class of the interstate waters of the state shall be such that after treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, plus additional pre, post, or intermediate stages of treatment, or other equivalent treatment processes, the treated water will meet in all respects the recommended requirements of the Public Health Service Drinking Water Standards--1962 for drinking water as specified in Publication No. 956 published by the Public Health Service of the U.S. Department of Health, Education and Welfare, and any revisions, amendments or supplements thereto. This standard will ordinarily be restricted to surface waters, and ground waters in aquifers not considered to afford adequate protection against contamination from surface or other sources of pollution. Such aquifers normally would include fractured and channeled limestone, unprotected impervious hard rock where water is obtained from mechanical fractures, joints, etc., with surface connections, and coarse gravels subjected to surface water infiltration. The concentrations or ranges given below shall not to exceeded in the raw waters before treatment:

Substance or Characteristic	Limit or Range
Fecal coliform organisms	200 most probable number/100 ml
Arsenic (As)	0.05 mg/liter
Barium (Ba)	1 mg/liter
Cadmium (Cd)	0.01 mg/liter
Chromium (Cr + 6)	0.05 mg/liter
Cyanide (CN)	0.2 mg/liter
Fluoride (F)	1.5 mg/liter
Lead (Pb)	0.05 mg/liter
Selenium (Se)	0.01 mg/liter
Silver (Ag)	0.05 mg/liter
Radioactive material	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

In addition to the above listed standards, no sewage, industrial waste or other wastes, treated or untreated, shall be discharged into or permitted by any person to gain access to any interstate waters classified for domestic consumption so as to cause any material undesirable increase in the taste, hardness, temperature, toxicity, corrosiveness or nutrient content, or in any other manner to impair the natural quality or value of the interstate waters for use as a source of drinking water.

Fisheries and Recreation

Class A: The quality of this class of the interstate waters of the state shall be such as to permit the propagation and maintenance of warm or cold water sport or commercial fishes and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the interstate waters are given as follows:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 7 mg/liter from October 1 and continuing through May 31, and Not less than 6 mg.liter at other times.

Substance or Characteristic	Limit or Range
Temperature	No material increase
Ammonia (N)	0.2 mg/liter
Chlorides (Cl)	50 mg/liter
Chromium (Cr)	0.02 mg/liter
Copper (Cu)	0.01 mg/liter or not greater than 1/10 the 96 hr TLM value.
Cyanides (CN)	0.2 mg/liter
Oil	0.5 mg/liter
pH value	6.5 - 8.5
Phenols	0.01 mg/liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams, prawns and like creatures. Where it seems probable tha a discharge may result in tainting of edible aquatic products, bio-assays and taste panels will be required to determine whether tainting is likely or present.
Turbidity value	10
Color value	30
Fecal coliform organisms	200 most probable number/100 ml as a monthly geometric mean based on not less than 5 samples/month, nor exceed 400 most probable number/100 ml in more than 10% of all samples during any month.
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

<u>Class B</u>: The quality of this class of the interstate waters of the state shall be such as to permit the propagation and maintenance of cool or warm water sport or commercial fishing and be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. Limiting concentrations or ranges of substances or

characteristics which should not be exceeded in the interstate waters are given below:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 6 mg/liter from April 1 through May 31, and Not less than 5 mg/liter at other times.
Temperature*	5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperature, except in no case shall it exceed the daily average temperature of 86°F.
Ammonia (N)	1 mg/liter

* The following temperature criteria will be applicable for the Mississippi River from Lake Itasca to the outlet of the Metro Wastewater Treatment Works in St. Paul in addition to or superseding the above. The weekly average temperature shall not exceed the following temperatures during the specified months:

January	40°F	July	83°F
February	40°F	August	83°F
March	48°F	September	78°F
April	60°F	October	68°F
May	72°F	November	50°F
June	78°F	December	40°F

For the Mississippi River from Lock and Dam No. 2 at Hastings to the Iowa Border, the weekly average temperature shall not exceed the following temperatures during the specified months:

January	40°F	July	84°F
February	40°F	August	84°F
March	54°F	September	82°F
April	65°F	October	73°F
May	75°F	November	58°F
June	84°F	December	48°F

Substance or Characteristic	Limit or Range
Chromium (Cr)	0.05 mg/liter
Copper (Cu)	0.01 mg/liter or not greater than 1/10 the 96 hr TLM value.
Cyanides (CN)	0.02 mg/liter
Oil	0.5 mg/liter
pH value	6.5 - 9.0
Phenols	0.01 mg/liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bioassays and taste panels will be required to determine whether tainting is likely or present.
Turbidity value	25
Fecal coliform organisms	200 most probable number/100 ml as a monthly geometric mean based on not less than 5 samples/month, nor equal or exceed 2,000 most probable number/100 ml in more than 10% of all samples during any month.
Radioactive materials	Not to exceed the lowest concentration permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

Class C: The quality of this class of the interstate waters of the state shall be such as to permit the propagation and maintenance of rough fish or species commonly inhabiting waters of the vicinity under natural conditions, and be suitable for baoting and other forms of aquatic recreation for which the interstate waters may be usable. Limiting concentrations or ranges of substances or characteristics which should not be exceeded in the interstate waters are given as follows:

Substance or Characteristic	Limit or Range
Dissolved oxygen	Not less than 5 mg/liter from April 1 through November 30, and not less than 4 mg/liter at other times.
Temperature	5°F above natural in streams and 3°F above natural in lakes, based on monthly average of the maximum daily temperature except in no case shall it exceed the daily average temperature of 90°F.
Ammonia (N)	1.5 mg/liter
Chromium (Cr)	0.05 mg/liter
Copper (Cu)	0.01 mg/liter or not greater than 1/10 the 96 hr TLM value.
Cyanides (CN)	0.02 mg/liter
Oil	10 mg/liter, and none in such quantities as to (1) produce a visible color film on the surface, (2) impart an oil odor to water or an oil taste to fish and edible invertebrates, (3) coat the banks and bottom of the watercourse or taint any of the associated biota, an (4) become effective toxicants according to the criteria recommended.
pH value	6.5 - 9.0
Phenols	0.1 mg/liter and none that could impart odor or taste to fish flesh or other fresh-water edible products such as crayfish, clams, prawns and like creatures. Where it seems probable that a discharge may result in tainting of edible aquatic products, bioassays and taste panels will be required to determine whether tainting is likely or present.
Turbidity value	25
Fecla coliform organisms	200 most probable number/100 ml as a geometric mean nor equal

Substance or Characteristic	Limit or Range
	or exceed 2,000 most probable number/100 ml in more than 10% of the samples.
Radioactive materials	Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use.

GENERAL STANDARDS APPLICABLE TO ALL INTRASTATE WATERS OF THE STATE (WPC 15)

1. No untreated sewage shall be discharged into any intrastate waters of the state. No treated sewage, or industrial waste or other wastes containing viable pathogenic organisms, shall be discharged into intrastate waters of the state without effective disinfection. Effective disinfection of any discharges, including combined flows of sewage and storm water, will be required where necessary to protect the specified uses of the intrastate waters.

2. No sewage, industrial waste or other wastes shall be discharged into any intrastate waters of the state so as to cause any nuisance conditions, such as the presence of significant amounts of floating solids, scum, oil slicks, excessive suspended solids, material discoloration, obnoxious odors, gas ebullition, deleterious sludge deposits, undesirable slimes or fungus growths, or other offensive or harmful effects.

3. Existing discharges of inadequately treated sewage, industrial waste or other wastes shall be abated, treated or controlled so as to comply with the applicable standards. Separation of sanitary sewage from natural run-off may be required where necessary to ensure continuous effective treatment of sewage.

4. The highest levels of water quality, including, but not limited to, dissolved oxygen, which are attainable in the intrastate waters by continuous operation at their maximum capability of all primary and secondary units of treatment works or their equivalent discharging effluents into the intrastate waters shall be maintained in order to enhance conditions for the specified uses.

5. Means for expediting mixing and dispersion of sewage, industrial waste, or other waste effluents in the receiving intrastate waters are to be provided so far as practicable when deemed necessary by the Agency to maintain the quality of the receiving intrastate waters in accordance with applicable standards. Mixing zones be established by the Agency on an individual basis, with primary consideration being given to the following guidelines: (a) mixing zones in rivers shall permit an acceptable passageway for the movement of fish; (b) the total mixing zone or zones at any transect of the stream should contain no more than 25% of the crossectional area and/or volume of flow of the stream, and should not extend over more than 50% of the width; (c) mixing zone characteristics shall not be lethal to aquatic organisms; (d) for contaminants other than heat, the 96 hr median tolerance limit for indigenous fish and fish food organisms should not be exceeded at any point in the mixing zone; (e) mixing zones should be as small as possible, and not intersect spawning or nursery areas, migratory routes, water intakes, nor mouths of rivers; and (f) overlapping of mixing zones should be minimized and measures taken to prevent adverse synergistic effects.

6. It is herein established that the Agency shall require secondary treatment as a minimum for all municipal sewage and biodegradable industrial or other wastes to meet the adopted water quality standards. A comparable high degree of treatment or its equivalent also shall be required of all nonbiodegradable industrial or other wastes unless the discharger can demonstrate to the Agency that a lesser degree of treatment or control will provide for water quality enhancement commensurate with present and proposed future water uses and a variance is granted under the provisions of the variance clause. Secondary treatment facilities are defined as works which will provide effective sedimentation biochemical oxidation, and disinfection, or the equivalent, including effluents conforming to the following:

Substance or Characteristic	Limiting Concentration or Range*
5-Day Biochemical Oxygen Demand	25 mg/liter
Fecal coliform group organisms	200 most probable number/100 ml
Total suspended solids	30 mg/liter
Pathogenic organisms	None
Oil	Essentially free of visible oil
Phosphorus**	1 mg/liter
Turbidity	25
pH range	6.5 - 8.5
Unspecified toxic or corrosive substances	None at levels acutely toxic to humans or other animals or plant life, or directly damaging to real property.

In addition to providing secondary treatment as defined above, all dischargers of sewage, industrial wastes or other wastes also shall provide the best practicable control technology not later than July 1, 1977.

* The arithmetic mean for concentrations of 5-day biochemical oxygen demand and total suspended solids shall not exceed the stated values in a period of 30 consecutive days and 45 mg/liter in a period of 7 consecutive days. Disinfection of wastewater effluents to reduce the coliform organisms levels is required year around. The geometric mean for the fecal coliform organisms shall not exceed the stated value in a period of 30 consecutive days and 400 most probable number/100 ml in a period of 7 consecutive days. The application of the coliform and pathogenic organism standards ordinarily shall be limited to sewage or other effluents containing admixtures of sewage and shall not apply to industrial wastes except where the presence of sewage, fecal coliform organisms or viable pathogenic organisms in such wastes is known or reasonably certain.

** Where the discharge of effluent is directly to or affects a lake or reservoir. Removal of nutrients from all wastes shall be provided to the fullest practicable extent wherever sources of nutrients are considered to be actually or potentially detrimental to preservation or enhancement of the designated water uses.